ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

INVESTIGATING THE CAUSES OF FREQUENT FAILURES ON MAINTAINED ASPHALT PAVEMENT FEDERAL ROADS IN ETHIOPIA

By

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A Thesis Submitted to The College of Architecture and Civil Engineering for the Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Technology and Management

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MAY, 2018

DECLARATION

I hereby declare that this thesis entitled "**Investigating the Causes of Frequent Failures on Maintained Asphalt Pavement Federal Roads in Ethiopia"** was composed by myself, with the guidance of my advisor, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

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APPROVAL PAGE

This MSc thesis entitled with **"Investigating the Causes of Frequent Failures on Maintained Asphalt Pavement Federal Roads in Ethiopia"** has been approved by the following examiners after the thesis presentation on the masters of Science in Civil Engineering (Construction Technology and Management Stream).

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ABSTRACT

Ethiopia has lost precious infrastructure worth billions of dollars through unnecessary deterioration of the national roads (Jovanovic, 2014). Large road networks, built at great expense, have been improperly maintained; more heavily used and abused than expected. If this neglect continues, the deterioration of maintained roads will accelerate as old pavements crumble and new ones outlive the initial period during which the effects of neglect are barely perceptible.

Therefore, the Ethiopian road networks are in deplorable condition. The Government expenditure on roads accounts for a quarter of a years' infrastructural budget. The intention towards maintaining already existing roads is given less emphasis but causing much damage to the country's ongoing development in the road sector. In this study, document review, observation and questionnaire survey methods were used to gather the required data. During document review, three years annual reports of pavement maintenance roads were acquired from the Central District Region of the ERA. Similarly, data were acquired from contractors and consultants that were involved in road maintenance activities and from maintained road users from selected sites to investigate the factor that cause failures of maintained roads. During visual observation, five sites were selected and the results revealed that the maintained roads were utilized by overloaded trucks, pavements were aged, severe weather was witnessed, drainages were poor, the construction quality was poor and the construction materials were substandard, the maintenance management system were poor and all the above in aggregated caused pavement deterioration of the maintained roads.

In addition to document review and observation, a questionnaire survey was conducted and results were analyzed using average index according to participants' perspectives. The findings of questionnaire showed that workers' skill, maintenance culture, quality materials and soil condition, uneven increase/fluctuation of material price, shortage of material, manpower and lack of efficient/competent contractor were the major causes for pavement deterioration. In addition, budget constraints, limited skilled manpower and absence of appropriate machinery were the major constraints for implementation of effective road maintenance works at the ERA costing the Nation dearly. Increase in travel time, increase in fuel consumptions on frequently maintained asphalt pavement roads implied that the road users were not satisfied either.

Finally, possible recommendation forwarded as per the achievement of analysis in order to improve the major causes and minimize the problems of poor maintenance culture through using maintenance procedures applied in Ethiopia.

Key Words; Causes, Frequent Failures, Maintained Roads, Asphalt Pavement, Federal Roads and Road users

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GLOSSARY

Major Causes: a main reason for an action or condition

Frequent Failures: Failures of road maintenance resulting from the same direct cause, occurring within a relatively short time, where these failures are not consequences of another. NOTE Components that fail due to a shared cause normally fail in the same functional mode.

Maintained Roads: Preserved and kept roadway, roadside, structures as nearly as possible in its original condition as constructed or as subsequently improved and the operation of highway facilities and services to provide satisfactory and safe transportation.

Highway is a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by automobile, cart, bicycle, or horse.

Asphalt Pavement: it refers to any paved road surfaced with asphalt. Hot Mix Asphalt (HMA) is a combination of approximately 95% stone, sand, or gravel bound together by asphalt cement, a product of crude oil.

Asphalt cement is heated aggregate, combined, and mixed with the aggregate at an HMA facility. The resulting Hot Mix Asphalt is loaded into trucks for transport to the paving site

Federal Roads: The Federal roads were one instance of the federal government's agenda of "internal improvements," government-subsidized projects that would tie together the trade and people of the regions within country.

Maintained Road users: anyone who uses a maintained road, such as a pedestrian, cyclist or motorist.

Pavement: the total thickness of pavement including surfacing, base and sub-base.

Road Maintenance: Any activity undertaken to preserve the original surface and structural qualities of a road or a pavement.

Maintenance Management System: The process of organizing, scheduling and controlling maintenance activities to make the best possible use of resources available.

Pavement Management System (PMS): It is defined as the process of coordinating, planning and programming a comprehensive set of activities -- including construction, maintenance and rehabilitation -- to minimize the whole life cost of the road.

Skid Resistance: Attainable friction between the road surface and the tyres of vehicles affecting the functional condition of a road (pavement) which is expressed by indicators such as braking force coefficient, sideways force coefficient, skid number (present normalized gradient), skid number (speed gradient), etc.

Routine Road Maintenance: It comprises a range of small scale and simple activities - usually carried out at least once a year - but usually widely dispersed.

Periodic Road Maintenance: It covers activities on a section of road at regular and relatively long intervals, aims "to preserve the structural integrity of the road".

Emergency Maintenance: It is occasionally; urgent, unplanned maintenance works may also be required - sometimes known as.

Ethiopia Road Authority: It is one of the organizations under the Ministry of Works and Urban Development and accountable to the Board, is responsible for planning and formulating long and short-term plans and programs for road construction, design, maintenance of trunk and major link roads, as well as for administration of contracts.

ABBREVIATIONS

AfDB: African Development Bank

BS: British Standard

CBR: California Bearing Ratio

CRNMD: Central Road Network Maintenance District

CSIR: Council for Scientific and Industrial Research

E.C.: Ethiopian Calendar

ECWC: Ethiopia Construction Works Corporation

ERA: Ethiopian Road Authority

FTP: Federal Traffic Police

FY: Fiscal Year

GDP: Gross Domestic Product

GNP: Gross National Product

GOE: Government of Ethiopia

GTP: Growth and Transformation Plan

ICBP: Interlocking Cement Concrete Block Pavement

IDA: International Development Association

IDAPAD: International Development Association Project Appraisal Document

MOT: Ministry of Transport

MRA: Municipal Road Authorities

MUDHC: Ministry of Urban Development and Housing Construction

NRSC: National Road Safety Council

OPRC: Output and Performance based Road Contract

PI: Plastic Index

PMS: Pavement Management System

PSIP: Public Sector Investment Programmes

ROCKS: World Bank's Road Costs Knowledge System

RRA: Regional Roads Authorities

RSDP: Ethiopia's Road Sector Development Programs

UN: United Nations

UNDP: United Nations Development Program

URRAP: Universal Rural Roads Access Program

USD ($): United State Dollar

VOC: Vehicle Operating Cost

WRD: Woreda Road Desks

CHAPTER ONE

INTRODUCTION

1.1 GENERAL

Modern societies use a range of engineered objects for many different purposes. The objects are designed and built for specific functions. These include a variety of products (used by households, businesses, and governments in their daily operations); plants; and facilities (used by businesses to deliver goods and services) and a range of infrastructures (networks such as rail, road, water, gas, electricity, dams, buildings) to ensure the smooth functioning of a society (AAAS, 1990).

Every designed and constructed object may become unreliable in the sense that it degrades with age and/or usage and ultimately fails. Merriam Webster dictionary definition of failure is "falling short in something expected, attempted, desired, or in some way deficient or lacking." From an engineering point of view, a designed and constructed object is said to have failed when it is no longer able to carry out its intended function for which it was designed and built for. Failures occur in an uncertain manner and are influenced by several factors such as design, manufacture (or construction), maintenance, and operation. In addition, the human factor is also important in this context (AAAS, 1990).

One of the failures of roads occur in the loss of physical infrastructure because of inadequate maintenance. Bad roads seldom discourage users or curb the volume of traffic. Instead, they raise the cost of road transport which is dominant mode of transport for both people and freight in most countries which is strongly true in Ethiopia. Insufficient spending for maintenance thus exacts hidden costs several times the cost of maintaining and restoring roads. Road users bear the impact of these additional costs, which dwarf the savings to a road agency from deferring or neglecting maintenance. Much of the problem of road maintenance is rooted in its economic and institutional aspects. Inadequate incentives and weak accountability derive from the characteristic separation of responsibilities and control between the providers and users of roads. Unlike most other types of infrastructure, roads are neither built nor maintained by those who use them to market output or services (Harral, 1988).

Therefore, road maintenance is essential to preserve the road in its originally constructed condition; protect adjacent resources and user safety and provide efficient, convenient travel along the route. Unfortunately, maintenance is often neglected or improperly performed resulting in rapid worsening of the road and eventual failure from both climatic and vehicle use impacts (Abdulkareem & Adeoti, 2010).

1.2 BACKGROUND OF THE STUDY

The construction sector plays an important role in the development not only of the sector itself but also of other economic sectors. Construction activity generally contributes much to the country's total activity, at least with the corresponding demand for materials and labor inputs. The swings in the level of construction activity tend to both magnify and lead the movements in the economy. As stated by the Ethiopian Roads Authority (2005), construction is widely acknowledged as the most important single constituent in a developing country's investment program with about 50% of total capital formation which is realized through the construction industry of the road sector. It also stated that construction accounts for 60% of the public capital investment in Ethiopia. With such a high contribution, the construction industry has a major influence on the economic growth of a country and is, conversely, dependent on the state of the economy for the realization of its potential (ERA, 2015).

One of the major construction sector in Ethiopia is road sector and accordingly the transportation sector plays a significant role in the national economic growth, social activities maximizing the utilization of the country's assets. However, an inefficient and ineffective transportation sector will adversely affect all other sectors of the economy.

The deterioration of a country's transport facilities is a clear indication of the decline of economic growth. Road deterioration has neither narrowed in developing countries in general and in Ethiopia in particular nor is a new concern for the World Bank which published the Road Maintenance Problem and International Assistance in 2016 to draw attention to the matter. What is new, however, is the scale to which road deterioration has progressed in so many developing countries. Neglected or delayed maintenance causes expensive re-constructions and rehabilitation requirements, affecting all sectors of the economy. Effective and efficient road maintenance is required to reduce the rate of deterioration which would prolong the life of the facility, lowers vehicle operating costs of the users by providing a good running surface (WB Maintenance, 2017).

Ethiopia's total road coverage has reached 120,000 km, in 2017 as said by Minister of Transport of Ethiopia (May, 2017), attributing the success to the huge investment on road infrastructure in the past 25 years. However, Ethiopia has a total of around 40,000 km. of roads under maintenance and has been figured out a maintenance work on an average of 20,000 km. annually by the Federal Road Agency (GOE, 2017).

In this study, the causes of frequent failure of maintained asphalt pavement Federal roads will be investigated based on the physical and financial magnitude of the deterioration and to identify remedial measures appropriate to the circumstances of different countries. Similarly, an effort will be

made to determine the major causes of paved maintained road deterioration and why and where from the problem has become so widespread. During the study, the selected sites will be carried out to study and to identify the causes of frequent failures of roads.

1.3 STATEMENT OF THE PROBLEM

Construction encompasses the issues relevant to the process of road construction and maintenance, including the design, contracting, implementation, supervision, and maintenance of roads and related structures. With respect to the factors that affect maintained asphalt pavement road, this includes the condition of maintained roads in general, as well as the contracting party of maintenance activities. In addition, issues related to the area of construction and the environment are also included, such as construction and maintenance environmental impacts and mitigation, and construction site safety for frequent failure of maintained roads.

Asphalt pavement road deterioration extended much faster than the corresponding maintenance budgets and institutional capacities. Traffic has also become much heavier than expected, and axle loadings have often exceeded the designed capacity of pavements. These patterns are evident almost everywhere. New asphalt pavement roads, if inadequately maintained, deteriorate regularly and almost imperceptibly during the first half to two-thirds of their service life, depending on the traffic and weather condition. After that grace period, which may last ten to fifteen years, the pavements deteriorate much more rapidly. Without timely maintenance, they break apart (Caltrans, 2001).

As roads become rougher, the costs of operating vehicles-and of transporting goods-begin to shoot up. The neglect of maintenance continues, however, the vehicle operators that pay these costs-and pass them on if they can. Road authorities are not directly affected by these costs, and they come under no immediate pressure to improve road conditions. Road users are often slow to see the link between road conditions and the prices of goods and transport services and are usually not organized to do something about it (Harral, 1988). One of the problems of the Federal Roads in Ethiopia is that annually, around half of the Federal road network is maintained and still the roads are grouped under poor and fair sate. Further, the cost of road maintenance has amplified in the past ten years. Therefore, the factor affecting maintained asphalt pavement roads either negatively or positively can be avoided or enhanced respectively using several engineering techniques. This study aims to assess the causes for frequent failures of maintained asphalt pavement Federal roads in Ethiopia and identify the corresponding positive and negative impacts.

1.4 RESEARCH QUESTIONS

- What are the major causes of frequent failures of maintained federal paved roads in Ethiopia?
- How often the asphalt pavement road maintenance carried out?
- Do the road maintenances practice follow the Ethiopian Road Authority standards?
- How does ERA evaluate the satisfaction of road users?

1.5 OBJECTIVE OF THE STUDY

1.5.1 GENERAL OBJECTIVE

The general objective of the study is to assess the causes of frequent asphalt pavement failures of maintained Federal Roads in Ethiopia.

1.5.2 SPECIFIC OBJECTIVES

The specific objectives of this study are to:

- identify the major factors that cause maintained asphalt pavement roads failure in highway;
- assess the road maintenance practice;
- evaluate the satisfaction of maintained road users and
- recommend intervention measures to minimize the frequent failure factors for maintained paved road.

1.6 SIGNIFICANCE OF THE STUDY

As roads pavement deteriorate and become rougher, the costs of operating vehicles and of transporting goods begin to shoot up. As the neglect of maintenance continues, it is the vehicle operators that will pay these costs-and pass them on to the consumers. Road authorities are not directly affected by these costs, and they come under no immediate pressure to improve road conditions. Road users are often affected by maintained road conditions and the prices of goods and transport services. The following are envisaged as the significance of this study:

- The primary significance of this research is to provide immediate benefits to road users by identifying the causes of frequent failures of the Federal paved road maintenance and provide recommendation to possibly solve these problems with desired recommendations.

- This research helps for road improvements followed by a well-planned program of maintenance. Without regular maintenance, roads can rapidly fall into disrepair, preventing realization of the longer-term impacts of road improvements on development, such as increased agricultural production and growth in school enrollment.
- Furthermore, the outputs of this research are envisaged to help the responsible authorities to see the effect of how severe the issue is such that great attention and participations on any research based on road maintenance related problems will be supported efficiently.

1.7 SCOPE AND LIMITATION OF THE STUDY

The scope of this research focused on investigating the cause of frequent failure of maintained asphalt pavement roads regarding the Federal Roads of Ethiopia. The study researched the failure level of maintained asphalt pavement road and the changes in various factor like: traffic condition, weather condition and performances of contractors and their effectiveness in road maintenance. This research was an attempt to provide recommendation for better measurement to prevent the failure of maintained asphalt pavement roads under the jurisdiction of the ERA, so that they can bring about changes in maintenance issues which will help them to develop a practical manual in maintenance supervision.

There was limitation which is encountered throughout the preparation of this study. The major limitation of this study was lack of relevant data. Unavailability of adequate documented information and unwillingness of Stakeholders i.e. client, consultants and contractors to give document was the limitations of this study. In addition to these, there was limitation on related research which closely focused on the study of failurity causes of maintained asphalt pavement road in Ethiopia. However, extensive literature search related to the topic and works on related topics have been explored in order to build a general insight about the topic under study.

1.8 STRUCTURES AND ORGANIZATION OF THE STUDY

Generally, this research consists of five chapters; Chapter One dealt with the proposal for identifying and defining the problems and setting up of the objectives of the study. Chapter Two concentrated on literature review and Chapter Three dealt with materials acquisition and methodology and Chapter Four focused on generated results and discussions. Lastly, Chapter Five incorporated conclusions and recommendations stated below Figure 1-1.

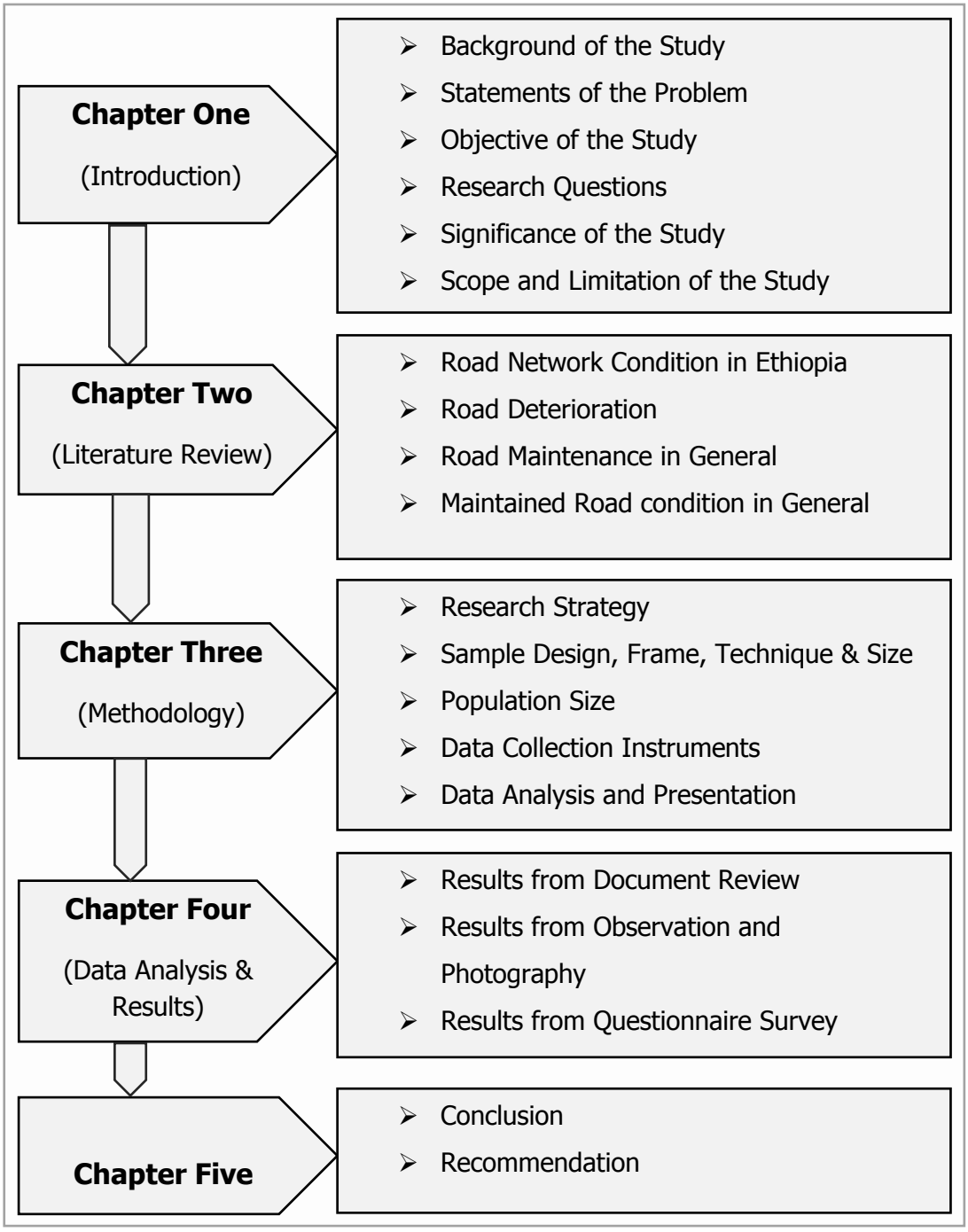


Figure 1- 1: The organization of the Study paper

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL

Cities in the developing nations are not only showing a rapid population growth, but also a change in their residents' way of life. This obviously implies that there is a need for a corresponding expansion of infrastructures and services (Haile Mekonnen, 2014). For the development of infrastructure in Ethiopia, there has been a massive increase in funds allocated for road construction over the last decade. The background history of Ethiopia's roads in the 17th and 18th centuries show that there were many small roads, trails and foot paths whereas the construction of modern roads started by the end of the 19^{th} century.

According to the ERA (2007), the state spending on roads accounted for a quarter of each year's infrastructure budget and the government had earmarked the equivalent of $4 billion to build, upgrade and repair of roads over the next ten years under the Road Sector Development Program (ERA, 2007). The state of road infrastructure revealed by available World Bank statistics in the 85 countries to which the World Bank has provided assistance for road development, 26 per cent of paved roads (some 270 000 km) and 32 per cent of unpaved main roads outside of urban areas were in "poor" condition and have already deteriorated to the point of needing reconstruction. Only around 30 per cent of the main road network was in fair condition (World Bank, 1990).

Khaing and Htwe (2014) conducted a study on “failures and maintenance of flexible pavement” for the economic development of a country's transportation system that takes a special role. By means of good transportation system; safe, rapid, comfortable and convenient, communication will be possible for people's mobility which is also essential for distribution of various goods in the country. This is basically important for economic, social and environmental development. They also stated that for a developing country a good highway system is very important to gain the way of modern society. Maintenance of the highway is very important for the whole traffic management. With weak maintenance system, various defects in the roads are main causes of accident. So, to be a successful engineer, a person should not only be able to design the road, but also should be skill-full to maintain the road (Khaing and Htwe,2014).

2.2 COUNTRY DEVELOPMENT AND ROAD MAINTENANCE

According to World Bank (1990), in road monitoring for maintenance management manual; Road transport in developing countries is an important sector of economic activity and investment, and functions as a catalyst to the overall economic and social development process. In particular, rural road accessibility is one of the key elements of small-holder development; most developing countries have agriculturally-based economies and road transport plays therefore an essential role in marketing agricultural (village) production. Road infrastructure is likewise important for providing access to health, education and agricultural extension services as well as the distribution of agricultural inputs such as fertilizer and pesticides.

And further stated World Bank (1990), during the boom years of road transport development in developing countries, priority was given to new construction and the remaining funds were insufficient for proper infrastructure maintenance. Furthermore, the small share of available resources which was used for maintenance purposes was often applied ineffectively. Over the years, the limited resources devoted to the upkeep of road networks together with the growth of heavy freight traffic have created a large backlog of road rehabilitation needs. The result is escalating road repair and vehicle operating costs as well as safety problems. Also, the capital invested in the transport fleet is used uneconomically. This is regrettable, because the budgetary constraints in developing countries demand the best possible use of available resources.

World Bank (2014) report on "Supports Road Improvements and Maintenance in Ethiopia" stated that timely road maintenance is important because it sustains the quality and safety of the road in a condition close to the original design, and minimizes the road user costs. It is also cheaper to regularly maintain a road in whole life cost terms, than to endure an ongoing cycle of un-managed deterioration and reconstruction. The impacts of inadequate maintenance can be felt immediately on the safety of the road and on vehicle performance. The World Bank's note on "Why road maintenance is important and how to get it done" gives a helpful overview of the arguments for timely road maintenance and advice on good practice.

If left unchecked, minor maintenance problems tend to become more serious and more expensive to repair. The South African National Road Agency Ltd. (SANRAL) estimates that repair costs can rise to six times maintenance costs after three years of neglect and to 18 times after five years of neglect. However, finding the necessary funding for maintenance can be difficult. In addition to these aspects associated with a properly maintained road system, there is also the question of protecting a large capital investment (the highway system) in a manner that will maximize the benefits of the

investment relative to the costs of protection, or in this case, maintenance. It is clear that timely and appropriate maintenance can slow the rate of deterioration, delay the need for major, expensive, repairs such as reconstruction, and generally extend the service life of a road to attain the highest economic benefit (World Bank, 1990)

Different scholars have studied on road maintenance cost as part of savings in the cost of preservation of national, investment on roads, substantial reduction in vehicle operating cost and other road User's benefits, other economic benefits of road maintenance that enhances national development are as follows, according to (Abdulkareem and Adeoti, 2010):

- **Employment Creation**: All road maintenance agencies create employment opportunities for various categories of citizens and help in poverty eradication.
- **Agricultural Production**: Past and present efforts in rural road maintenance are focused on improved agricultural production and creation of links between rural and urban areas for free movement of agricultural products.
- **Industrial Development**: The level of industrialization in any economy depends largely on the condition of its road network. This is why governments continued to pay great attention to road development and maintenance, as a catalyst for industrial growth.
- Manpower Development: The acquisition of technical skill in road maintenance by engineers and technologists through the various road maintenance agencies will assist a nation in its drive towards technological independence.

Research and Development: Challenges created by the road maintenance needs will open up opportunities for Research Institutions, Universities and Polytechnics in the area of cheaper road maintenance materials and methods. Teravaninthorn et al. (2014) discussed upgrading and maintenance works through OPRC?? and asset management contracts which will create jobs for the local people in Ethiopia. This includes unskilled labor required for the construction works and contractors' camp operations as well as skilled workers such as drivers and equipment operators. Contractors will engage local labor for roadside environmental protection activities and labor intensive works such as culvert clearing. During the maintenance period, routine activities, including bush clearing and cleaning drainage structures would be carried out by labor, hence creating local employment. Under the OPRC arrangements, the contractors may make use of the availability of local contractors and sub-contract the maintenance works.

Finally, it should be noted that an improperly maintained road system can present increased safety hazards to the highway users. These can lead to more accidents with their associated costs of human

death and injuries, property damage, etc., as well as human suffering. A proper road monitoring system will identify existing and potential safety hazards which an adequate maintenance programme will eliminate.

2.3 ROAD NETWORK CONDITION IN ETHIOPIA

According to International Development Association Project Appraisal Document (IDAPAD), Ethiopia is a large and diverse country. It is located in the Horn of Africa and is a land-locked country with an area of one million km^2 of land coverage and 104,300 $km^{2\ of}$ water body coverage. Its bio-physical environment includes a variety of contrasting ecosystems, with significant differences in climate, soil properties, vegetation types, and agricultural potential, biodiversity and water resources. Ethiopia is a country of many nations, nationalities and peoples, with a total population of 91.7 million in 2012 census (IDAPAD, 2014). Only 17 percent of the population lives in urban centers, the great majority of them live in Addis Ababa. At a current annual growth rate of 2.6 percent, Ethiopia's population is estimated to reach 130 million by 2025 and is projected by the UN to be among the world's top ten, by 2050 (Teravaninthorn et al., 2014).

Based on recently published data of the Government of Ethiopia (GOE) (2017), Ethiopia's road network has been improving each year. As of the end of FY 2016, Ethiopia had 113,066 kilometers (70,256 miles) of all-weather roads – about 30% of the required road network in the country. In FY 2015/16, the GOE invested Birr 47.5 billion ($2.11 billion) in road construction. In the past fifteen years, the GOE has been vigorously engaged in new road construction as well as expansion of the existing road network through Ethiopia's Road Sector Development Programs (RSDP).

In 2011, the GOE embarked upon RSDP Phase IV, the largest program undertaken in the sector. RSDP-IV is considered a strategic pillar of GOE's Growth and Transformation Plan (GTP), which plans to increase the road network from 49,000 kilometers (30,447 miles) to 136,000 kilometers (84,506 miles) over a five-year period. Unlike earlier phases of the RSDP, Phase IV places a high emphasis on improved access, specifically the construction of feeder/link roads and lower volume roads. According to 2014 UNDP Human Development report, Ethiopia has invested Birr 142 billion ($7.1 billion) on road construction projects over the past 16 years; out of which $ 5.4 billion (77%) was funded from internal sources (GOE, 2017).

Finally, Ken Gwilliam (2008) studied on Africa Infrastructure Country Diagnostic (roads in sub-Saharan Africa); viewed against the vastness of the subcontinent, the road network of Sub-Saharan Africa is sparse. Certainly, it is much less dense than the networks of other developing regions. But

viewed against the region's population and income hence its ability to pay for maintenance—road density begins to look rather high.

2.3.1 EXISTING AND NEW PAVED ROAD NETWORK CONDITION

Ken Gwilliam (2008) stated that on average, about half of the main network within urban area is in good condition and a further third in fair condition. The same cannot be said for the total country road network; only about a quarter of the road network is in good condition and a further quarter in fair condition. Gwilliam also viewed countries that devote a larger share of their road funds to maintenance (and that also have road agencies) show significantly better-quality indicators for their main road network; though, once again, no such clear relationship is found for rural roads in Ethiopia.

Variations in road quality across countries reflect both fundamental economic and geographic conditions, as well as the influence of institutional design and financing flows. According to Gwilliam (2008), GDP per capita is the factor most strongly correlated with the percentage of the main road network in good condition, reflecting effort devoted to the paved roads in the network. Climate and terrain, on the other hand, are the factors that best predict the percentage of the main and rural network in poor condition, because difficult climate and terrain speed the rate of deterioration. But, economic and geographic peculiarities do not explain all the variations in road quality across countries. Even controlling for income and climate, substantial variation can be seen in road quality across countries (Gwilliam, 2008).

For new paved road network condition, Neero Sorum (2014) stated on case study of pavement distress; pavement design is the process of developing the most economical combination of pavement layers (in relation to both thickness and type of materials) to suit the soil foundation and the cumulative traffic to be carried during the design life. Design of pavement structure differs from the design of buildings and bridges because pavement design is based on empirical or semi-empirical approach and there is no rational method of design. According to Sorum's case study (2014), pavement design consists of mainly two parts. The first is design of the material mixture to be used in each pavement component layer; and the second one is design of pavement structure (design of thickness and type of different component layers).

According to Survey and Evaluation of flexible Pavement Failures studied by Zumrawi (2015), pavement deterioration process starts directly after opening the road to traffic. Deterioration process starts very slowly so that it may not be noticeable and over time it accelerates at faster rates. To

ensure the risk of premature deterioration is minimized, it is necessary to use the best practice method in planning, design, construction and maintenance of the road. This can be achieved by examining pavements that have failed prematurely, with the focus being on determining the causes of failure so that it can be prevented in the future (Zumrawi, 2015). The greater understanding of pavement failures that could be gained from detailed investigations could be valuable in reducing the costs associated with pavement failures in the future. In many cases, the failure of pavement structure can be directly attributed to inadequate maintenance and ineffective evaluation programs. It is important to find out a method to minimize the maintenance cost under a limited budget (Madanat & Ben-Akiva, 1994). For that purpose, it is quite important to consider a simplified method for inspection and evaluation of pavement failures in road condition.

2.4 ROAD DETERIORATION

Wada and Abubakar (2016), stated that the developing countries have lost precious infrastructures worth billions of dollars through deterioration of their roads. If their government do not do much to prevent their roads, they will lose billions more. Large road networks, built at great expense have been under maintained and more heavenly used and abused than expected. If this continues, the deterioration of roads will increase rapidly as the old pavements crumble and the new ones outlive the initial period during which the effects of neglect are barely noticeable (CSIR,1997). The cost of restoring these deteriorated roads is going to be much higher than expected for the timely effective maintenance.

Besides on physical deterioration of road, Okikbo (2012), referred to the road defects as the visible evidence of undesirable condition in the pavement affecting the serviceability, structural condition or appearance. In his paper on road defects in Nigeria, he indicated that the defects that most often cause injuries to people or damage vehicles include; inadequate road shoulders, uneven lanes, improperly marked signs, malfunctioning stop lights, construction negligence and municipal negligence. Legal framework and transportation management are the national aims in decreasing the road deterioration (Okikbo, 2012).

Harral Clell (1988), summarized on "Road Deterioration in Developing Countries: Causes and Remedies"; the road deterioration problem pervades the developing world. The problems are those Sub-Saharan countries whose financial and institutional capacities are unequal to the task at hand or to the one they will soon have to face.

2.4.1 PHYSICAL MAGNITUDE OF DETERIORATED ROAD

World Bank (1990), viewed in its report the developing world's road building boom in the1960s and 1970s created an infrastructure that has been crumbling in the 1980s and threatens to collapse in the 1990s if not quickly strengthened and protected. Large road networks, built at great expense, have been inadequately maintained and used more heavily than expected.

According to Harral Clell (1988), the result in many developing countries is a network of deteriorating roads. Many roads are in such poor condition that normal maintenance is no longer sufficient or effective. These roads now require rehabilitation or reconstruction at three to five times the cost of timely preventive maintenance and strengthening.

More recently, Zumrawi (2015), studied on Survey and Evaluation of flexible Pavement Failures viewed that the Physical magnitude of deterioration of road is due to Pavement failure. Kumar & Gupta (2010), reported that before going into the maintenance strategies, highway engineers must look into the causes of failures of bituminous pavements. They found that failures of bituminous pavements are caused due to many reasons or combination of reasons. It has been seen that only three parameters i.e. unevenness index, pavement cracking and rutting are considered while other distresses have been omitted while going for maintenance operations.

As stated by Woods and Adcox (2004), paved road deterioration may be considered as structural, functional, or materials failure, or a combination of these factors. Structural failure is the loss of load carrying capability, where the pavement is no longer able to absorb and transmit the wheel loading through the structure of the road without causing further deterioration. Functional failure is a broader term, which may indicate the loss of any function of the pavement such as skid resistance, structural capacity, and serviceability or passenger comfort. Materials failure occurs due to the disintegration or loss of material characteristics of any of the component materials. And also, Caltrans (2001) categorized the main types of paved roads physical deteriorations as either deformation failures or surface texture failures. Deformation failures include: corrugations, depressions, potholes, rutting and shoving.

In many paved road deterioration, excess moisture is the main reason of weakening or a contributing cause. Queensland Transport reported the effect of moisture content changes on the strength and stiffness of pavement materials. They found that excess moisture reduces the strength and stiffness of pavement materials, being worse for the subgrade material, than for the subbase or base. Excess

moisture and particularly high degrees of saturation result in significant pore pressures within the material. Depending on the degree of saturation, failure may occur as any of rapid shear or bearing failure, premature rutting, lifting of wearing course due to positive pore pressures, or embedment of cover aggregate due to weak base, (Queensland, 2012).

2.4.2 FINANCIAL MAGNITUDE OF DETERIORATED ROAD

Countries differ widely in their financial requirements for road maintenance and restoration; their ability to marshal and allocate the needed resources, and their capacity to use additional resources effectively. And also the financial severity of a country's road restoration requirements can be evaluated in two ways according to the study of Harral (1988). One is to estimate how much the current funding for maintenance could be increased by reallocating funds within the overall budget for the sector and the other is to look at the rate of growth of real GNP per capita.

Then, the financial requirements of the road deterioration problem have two parts. One is the cost to restore (rehabilitate or reconstruct) those roads that are in poor condition and warrant saving. The other is the future annual cost of maintaining the whole network at economically warranted standards (Harral, 1988). Harral also explained current road budgets (based on funding from domestic sources and, in some cases, external assistance) were placed in three broad categories according to their adequacy for restoration of the road network. These are sufficient financing capacity; moderate to marginal financing capacity; and insufficient financing capacity.

Unambiguously, Oladele and Egwurube (2011) studied on "highway maintenance cost estimation modeling for developing countries: a case study of Nigeria"; discussed that the cost of road maintenance depends on a number of factors, notable among them being the volume and intensity of traffic; cost of materials, labor and machinery; type of terrain; type of wearing surface; the minimum level of serviceability considered acceptable for that category of highway; and climatic conditions. In addition to this they refers road maintenance costs are partly a function of highway design variables such as: length and width of road; composition and thickness of the pavement; and strength of the subgrade.

The product of the road length and respective width determines the total area of highway to be maintained. The section of the road maintained is a proportion of the total area. Depending on the level of deterioration the proportion vary from a small fraction to total area. The structural components characterized by the subgrade strength, composition and thickness of the pavement affect the rate of highway deterioration. The resulting impacts of the designed variables determine the frequency and extent of appropriate maintenance operations and policies.

In the United States of America (USA) when its highway network was rapidly expanding, the initial construction cost was the most important issue, with little or no attention being paid to the ongoing maintenance costs (ARRA, 2001). However, as the highway network matured, traffic volume and gross vehicle weights increased, and as funds became more tightly budgeted, increased emphasis were placed on preventive maintenance and preservation of the existing highways. In many jurisdictions, the funds available were not able to keep pace with the increased preventive maintenance and preservation costs as the highway network aged. This resulted in a significant reduction in the condition and the level of service provided by the highways within the network. This in turn resulted in increased overall preventive maintenance and more expensive rehabilitation costs (Oladele and Egwurube, 2011).

Harral Clell (1988), concluded that the costs to road authorities are only the tip of the iceberg, for the costs to road users operating vehicles on rough roads are much larger. High haulage costs constrain the location of economic activity, hamper the integration of economic markets, limit the gains from specialization, and render unviable many activities that rely on road transport. The main networks generally include the principal roads and highways that cross urban areas or provide access to ports. Harral also briefed the problems of poor maintenance are worse for roads than for other sectors for three reasons; such as the costs and financial requirements are large; road deterioration accelerates with time; and road authorities are insulated from the effects of under-maintenance.

2.5 ROAD MAINTENANCE

2.5.1 GENERAL

Capital intensive projects should be executed when it is clear that they would contribute positively to the socio – economic well-being of the residents in the area, where such projects are to be located (Oladele and Egwurube, 2011). Hence, they said the maintenance of road will impact positively in terms of: faster and more comfortable travel time; opening-up of the farmlands; easier access of harvested food and cash crops to the more urban locations; reduce the rate of deterioration of the road and this prolong its life; lower the cost of operating vehicles on the road by providing good running surfaces; and enable greater regularity, punctuality and safety of road transport service.

Jim Campbell (2017) did a study on Road Maintenance Techniques in Ireland; the maintenance of roads involves the co-ordination of a wide range of seemingly unrelated activities in practice to achieve a good standard of effective maintenance it is essential that different aspects of the work should integrate smoothly. The task facing the Engineer in Road Maintenance is to maintain a

network of roads within available budgets. This is made difficult by the amounts of road which are built to inadequate standards and the increase in both the volumes of traffic and in the axle loadings combined with decreasing budgets and the expectation of further cuts in public expenditure.

This is noticeable both in rural areas where the intensification and diversification of agricultural production has resulted in minor roads of minimal pavement construction having to accommodate relatively large volumes of traffic and more particularly commercial vehicles which on occasion can barely fit onto the road, and in urban areas where the growth of towns and cities has incorporated areas serviced by minor roads now carrying heavy volumes of traffic (Jim C., 2017).

2.5.2 DEFINITION OF ROAD MAINTENANCE

2.5.2.1 HIGHWAY

Highway is a term commonly used to designate major roads intended for travel by the public between important destinations, such as cities (Oladele et al., 2011). According to ERA highway is defined as a major road, usually connecting two or more cities, ports, airports and regions, which is the recommended route for long-distance and freight traffic. Many trunk roads have segregated lanes in a dual carriageway, or are of motorway standard (ERA, 2015).

The Highway Design Manual however uses the term highway or arterial highway to define the through traffic usually on a continuous route, a facility designated with controlled access. In order to avoid the difficult drainage and maintenance problems, the road pavements are generally made on embankments, slightly above the general ground level. Since road pavement is slightly raised from general ground level the term road or roadway has been termed highway ‘summarized that a highway is an arterial road facility designed for high speed and high-volume traffic in the non-urban areas (Oladele et al., 2011).

Moreover, pavement means the surfacing layer only (Rangwala, 2013). But in highway design, it means the total thickness of pavement including surfacing, base and sub-base if any. It is a hard crust constructed over the natural soil for the purpose of providing stable and even surface for the vehicles. Therefore, it is a structure consisting of superimposed layers of materials above the natural soil subgrade, whose primary function is to distribute the applied vehicle loads to the subgrade (Wada and Surajo, 2016).

Based on the structural behavior and for design purposes, the road pavements are generally classified into two categories namely (Wada and Surajo, 2016); the first one is flexible pavement, and the second is rigid pavement. Other types of pavement structure include semi-rigid pavement or

composite pavement and interlocking cement concrete block pavement (ICBP). However, these types of pavements are less common when compared to flexible and rigid pavement (Khanna et al., 2014).

2.5.2.2 ROAD MAINTENANCE

According to Mohamed (2010), based on road maintenance management system view; the definition of maintenance varies among agencies. In a physical sense, maintenance consists of a set of activities directed toward keeping a structure in a serviceable state. For pavement, this includes such work as patching, crack sealing, filling and so on. Following are some definition of maintenance from different sources.

- Definition from BS3811: 1984 describes maintenance as combination of technical and management work done on a specific asset or structure to ensure the structure is in good condition and is functioning at its maximum capacity. They are two types of maintenance which maintenance involving repairing work and maintenance involving prevention work.
- Definition from Oxford Advance Learner's English Dictionary describes maintenance as the action of maintaining something or the state of being maintained.
- From Mohamed (2010), definition of pavement maintenance can be described as methods and techniques used to restore or maintain a specified level of service and to prolong pavement life by slowing its deterioration rate.
- According to Road Monitoring for Maintenance Management Manual for Developing Countries (World Bank, 1990), the following Terms are elaborated:
  - ✓ **Maintenance:** Any activity undertaken to preserve the original surface and structural qualities of a road or a pavement; Deferred maintenance, functional maintenance, periodic maintenance, preventive maintenance, programmed maintenance, remedial maintenance, routine maintenance, structural maintenance, surface maintenance.
  - ✓ **Maintenance Management System:** The process of organizing, scheduling and controlling maintenance activities to make the best possible use of resources available.
  - ✓ **Pavement Management System (PMS):** PMS is defined as the process of coordinating, planning and programming a comprehensive set of activities -- including construction, maintenance and rehabilitation -- to minimize the whole life cost of the road.
  - ✓ **Skid Resistance:** Attainable friction between the road surface and the tyres of vehicles affecting the functional condition of a road (pavement) which is expressed by indicators such as braking force coefficient, sideways force coefficient, skid number (present normalized gradient), skid number (speed gradient), etc.

Moreover, Burningham and Stankevich (2005), said on their study of "Why road maintenance is important and how to get it done"; road maintenance includes minor repairs and improvements to eliminate the cause of defects and to avoid excessive repetition of maintenance efforts. The goal of maintenance is to preserve the asset, not to upgrade it. Unlike major road works, maintenance must be done regularly. Road maintenance comprises "activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the road margins as near as possible to their as-constructed or renewed condition" (PIARC, 1994).

According to Abdulkareem and Adeoti (2010), road maintenance involves activities programmed to preserve the road infrastructure. This means that during the design life of the road, conscious efforts must be made to arrest the various deteriorations that take place on it. The purpose of the maintenance is to ensure that the road provides an acceptable level of service to the users for substantial period of its service life.

As a summary, the main and only objective of maintenance is to ensure the specific structure being maintained is in a good and acceptable condition and will not cause inconvenience to the users.

2.5.3 TYPES OF ROAD MAINTENANCE

Transport infrastructure - roads, railway, tracks and stations, ports and airports, and even the most basic rural facilities - all require maintenance, sometimes known as 'conservation'. Maintenance ensures that the asset continues to function as designed or intended, and meet the required quality standards throughout its anticipated lifetime. It can also extend the life of the asset beyond the original 'design life'. As stated by Burningham and Stankevich (2005), for management and operational convenience, road maintenance is categorization based on the nature of the activity and the frequency at which they should be carried out as routine, periodic, and urgent.

2.5.3.1 ROUTINE MAINTENANCE

Routine maintenance comprises a range of small scale and simple activities - usually carried out at least once a year - but usually widely dispersed. Typical activities include roadside verge clearing and cutting back encroaching vegetation, cleaning of silted ditches and culverts, patching and pothole repair, and light grading/reshaping of unsealed surfaces. Which also comprises small-scale works conducted regularly, aims "to ensure the daily passability and safety of existing roads in the short-run and to prevent premature deterioration of the roads and frequency of activities varies but is generally once or more a week or month" (PIARC 1994). Also, Burningham and Stankevich (2005), refers maintenance may be able to use unskilled/skilled labour, or labour based methods supported

by light equipment. So, conventional or community contracting may be appropriate. These regular operations are a good opportunity to identify periodic maintenance needs.

Furthermore, Cerlanek et al. (2006), stated on their maintenance of paved and unpaved roads in Alachua county gave other name for routine maintenance is routine works. These are works that are undertaken each year that are funded from the recurrent budget. Activities can be grouped into cyclic and reactive works types. Cyclic works are those undertaken where the maintenance standard indicates the frequency at which activities should be undertaken. Examples are verge cutting and culvert cleaning, both of which are dependent on environmental effects rather than on traffic levels. Reactive works are those where intervention levels, defined in the maintenance standard, are used to determine when maintenance is needed. An example is patching, which is carried out in response to the appearance of cracks or pot-holes (Cerlanek et al., 2006).

Based on the above researchers' explanation, routine maintenance consists of operations that normally need to be repeated one or more times every year, e.g. control of vegetation, cleaning of ditches and culverts, maintenance of bridges, crack sealing, seal coats, maintenance of road signalization and repairs to shoulders.

2.5.3.2 PERIODIC MAINTENANCE

According to World Bank Supports for Road Improvements and Maintenance in Ethiopia (2014); Periodic maintenance occurs less frequently - usually after a number of years. Works can include regravelling, resurfacing, resealing and repairs to structures. It is normally large scale and usually requires standard or specialist equipment and skilled resources.

Over and above explanation, periodic maintenance, which covers activities on a section of road at regular and relatively long intervals, aims "to preserve the structural integrity of the road" (WB Maintenance, 2017). These operations tend to be large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and often even design. Activities can be classified as preventive, resurfacing, overlay, and pavement reconstruction. Resealing and overlay works are generally undertaken in response to measured deterioration in road conditions. For a paved road, repaving is needed about every eight years; for a gravel road, re-graveling is needed about every three years (Burningham and Stankevich, 2005).

As a conclusion, a pavement is subjected to significant traffic and the ageing process progress, sufficient distress occurs. These activities are required to maintain acceptable safety, adequate

drainage and adequate riding surface, and retard the failure of the various pavement layers. Such activities include, regravelling of gravel roads, re-surfacing of bituminous surface dressing and paved roads (Abdulkareem et al., 2010).

2.5.3.3 URGENT MAINTENANCE

Occasionally; urgent, unplanned maintenance works may also be required - sometimes known as Emergency Maintenance - for example because of particularly severe weather conditions, floods, unexpected deterioration, or damage caused by vehicles. Burningham and Stankevich (2005), defined that urgent maintenance is undertaken for repairs that cannot be foreseen but require immediate attention, such as collapsed culverts or landslides that block a road.

In other words, according to Cerlanek et al. (2006), urgent maintenance is special maintenance works. These are activities whose need cannot be estimated with any certainty in advance. The activities include emergency works to repair landslides and washouts that result in the road being cut or made impassable. A contingency allowance is normally included within the recurrent budget to fund these works, although separate special contingency funds may also be provided.

Another type of road maintenance which is based on fund source and country strategy, Cerlanek et al. (2006), categorized development maintenance. These are construction works that are identified as part of the national development planning activity. As such, they are funded from the capital budget. Examples are the construction of by-passes, or the paving of unpaved roads in villages.

As conclusion, the above three maintenances are used according to its need. Hence, proper road maintenance contributes to reliable transport at reduced cost, as there is a direct link between road condition and vehicle operating costs (VOCs). An improperly maintained road can also represent an increased safety hazard to the user, leading to more accidents, with their associated human and property costs (Cerlanek et al., 2006).

2.5.4 ROAD MAINTENANCE PERIOD

According to Jim Campbell (2017), the structural design of the road pavement is determined by the estimated traffic volume over the design life of the pavement and the ground conditions, giving a depth of layered construction to provide for a 20-year life. Pavement overlays are designed on the basis of strength testing and the relevant depth of construction is added to the road structure. Cerlanek et al. (2006), stated that roads with high traffic counts had priority over roads with low traffic counts. Roads that had a high accident rate or a potential for accidents had priority over roads with a low accident rate or potential. Roads with a high pre-paving maintenance costs had priority

over roads with low maintenance costs. Roads with greater access to adjacent lands had priority over roads with lesser access. Roads that connected two paved roads or extended into areas of known growth had priority over roads that did not connect or extend into areas of known growth. Roads that had a high degree of citizen interests for paving had priority over roads with little citizen interest. Roads of which the right-of-way has been held by the County for a long time had priority over roads of which the right-of-way had been held for a short time.

Cerlanek et al. (2006) also stated that the methodology should also consider such important characteristics as traffic volumes, public health, life-cycle cost, safety, environment, roadway functional classification, available right-of-way, and citizen interest. Another problem created by unpaved roads is the health issues associated with particulate matter. The Environmental Protection Agency of USA associates certain detrimental health conditions with exposure to particulate matter.

The considerable variation in road conditions from country to country and region to region stems from differences in the past maintenance needs of individual networks and the countries' responses. Harral (1988) stated that the maintenance needs of a road network can be predicted fairly accurately from a set of structural characteristics, such as age, climate, traffic, design standards, construction quality, and subsequent maintenance. Of these, age, traffic, and construction quality are of particular importance in the developing countries to assign maintenance period.

Age is important to the condition of paved roads because of the time path of their deterioration. Typically, two-thirds of pavement deterioration (and an even higher proportion of maintenance cost) is concentrated in the final third of the design life of the pavement (Harral, 1988). The age of networks and the growth of traffic explain some differences in maintenance requirements, but the present condition of the roads reflects the extent to which maintenance requirements have been met in the past. Inadequate maintenance is largely the result of ineffective schedule, misallocated funds, unsound maintenance strategies, and inefficient implementation.

2.5.5 CAUSES OF THE FAILURES OF ROAD MAINTENANCE

2.5.5.1 GENERAL

According to Tarawneh and Sarireh (2013), road deterioration is common in developing countries. Keeping roads in good condition is the most cost-effective way to save highways. The accurate prediction of rutting development is an essential element for the efficient management of pavements systems. Okikbo (2012), refers to road defects as the visible evidence of an undesirable condition in the pavement affecting serviceability, structural condition or appearance. He also indicated that, the definition of "road defect" includes any part of a road, highway, or construction site that does not

meet the regulations for a safe road. In addition to that; in his paper on road defects in Nigeria he indicated that the defects that most often cause injuries to people or damage to vehicles include: inadequate road shoulders, lanes that are uneven pavement, improperly marked signs, malfunctioning stop lights, construction negligence, and municipal negligence.

In addition, climate conditions were seen to have an effect on road deterioration, vehicle operating costs, road safety and the environment (Anyala et.al. 2011). Transport Canada (2005) indicated that climatic factors are a major cause for pavement deterioration. It is a fact that temperature, frost and thaw action as well as moisture are factors that can cause certain types of pavement deterioration. These factors can also intensify pavement deterioration caused by heavy vehicles.

Adeoti (2004), examined the method of road maintenance in Nigeria. To do so, Adeoti defined and analyzed the causes of structural failure of highway pavement and suggest some factors; action of weather, rain and heat, unstable ground conditions and poor drainage, poor construction material and methods, post construction activities like digging of trenches along the road etc., poor workmanship and inadequate maintenance. On his study on Nigeria highway, Okikbo (2012), identified some of the factors that cause highway failure. These factors were; poor design and construction, poor maintenance of already built highways, use of low quality materials in construction, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road. Furthermore, he also suggested that the following will lead to highway failure such as; poor highway facilities, no knowledge base, inadequate sanction for highway failure, no local standard of practice, poor laboratory in situ tests on soil and weak local professional bodies in highway design, construction and management.

The most significant road defects observed in the field were: potholes, cracks, edge defects, depressions and corrugation (Harischandra and Randu, 2004). At the same time, they emphasized that traffic overloading, pavement age, road geometry, weather, drainage, construction quality as well as construction materials, maintenance policy play the major role as road deterioration agents. However, understanding the causes for pavement deterioration failures is an essential step towards minimizing risks to have good road performance. Some of the causes for failures on maintained paved roads are described as follows.

2.5.5.2 POOR ASPHALT ROAD MAINTENANCE CONSTRUCTION

According to Oguara (2010), failures like cracking in rigid pavement that are caused by inadequate curing of concrete, settlement, movement or restraint at joints may also lead to the development of cracks and subsequent failure. Most of the roads in developing countries are designed by concerned government agencies or by consultants some of whom are not within the environment of the road work. This leads to where preliminary studies of the environment that will help the design and construction decisions are not done. This also leads to poor understanding of the road environment which subsequently leads to poor road design and construction. Oguara (2010), then said that to save the road network from total collapse, requires good and efficient management which had to be done in a pragmatic and organized framework.

2.5.5.3 Heavy Traffic

According to Okigbo (2012), all road surfaces wear under the action of traffic, particularly during the very early life of the road. But within a short time, the micro texture reaches an equilibrium level and thereafter the low speed skidding resistance remains reasonably constant. However, the action of traffic continues to wear the macro surface texture and thus gradually reduces the high-speed skidding resistance. Oguara (2010) stated that with the increase of traffic loads both in terms of numbers and axle loads due to increased economic and developmental activities in the country, the road network experiences a systematic deterioration equivalent to an asset loss of about USD 124 billion due to road deterioration and vehicle operating cost of USD 83.39 billion per annum. One of the defects caused by heavy traffic on the road is the deformation of the roadway which is the change in a road surface from the intended profile. This results due to the application of overload that is beyond what the roadway is designed and constructed for (Oguara , 2010).

Nowadays, the rate of traffic accident on roads due to the nature of the road is alarming. Okigbo indicated that the defects that most often cause injuries to people and damage to vehicles include inadequate road shoulders, pavement surface that is uneven, improperly marked signs, malfunctioning stop lights, construction negligence, and municipal negligence. Traffic volume and size (especially for overloading) contributes to road safety and conditions. Recognizing of vehicles' uses and applications (industrial transportations) is the key for decreasing road deterioration (Zumrawi , 2016).

2.5.5.4 POOR MAINTENANCE CULTURE

Even if the roads are well built they need adequate maintenance for sustainability. One of the main problems of highway development is lack of proper maintenance. The roads are rarely maintained and whenever maintenance is attempted it is done haphazardly. According to Oguara (2010), the financing of the maintenance, rehabilitation and conservation of the roads network had always been left to government at the federal, state and local government levels because of their lack of maintenance culture do not release funds for road maintenance at the appropriate time. The road network was therefore left to deteriorate to the extent that portions of the federal trunk roads became impassable. Igomu (2011) stated that roads worldwide were considered critical infrastructure in any nation's life and were paid premium attention. However, Igomu (2011) said that was not the case with Nigeria, as many of the roads had exceeded their structural life and had become huge slaughter slabs as they had been denied all forms of maintenance. Igomu (2011) further said, adequate funds are not allocated for maintenance in Nigeria and also budgetary process is cumbersome and agencies in charge of maintenance are not well monitored for efficient work.

2.5.5.5 POOR HIGHWAY FACILITIES

According to Igomu (2011), highway facilities like drainages when not in use or lacking in performance result in some of environmental related defects like roadway deformations and pot holes. As at 2011, virtually all roads in the Nigeria have become hubs of intractable blockages and distressing motor accidents, as unsuspecting motorists speed into deadly depressions and monstrous potholes (Igomu 2011). The situation degenerates by the day aided by the rains and failed drainages filled with silts.

2.5.5.6 POOR LABORATORY AND INSITU TESTS ON SOIL

There is the need for adequate test of soil and the materials used for road construction. According to Okigbo (2012), unfortunately this is not always done due to lack adequate laboratory facilities and trained laboratory manpower for the job. Since most of the construction companies in Nigeria could not afford adequate laboratory facilities, they should make use of the laboratories in the universities and polytechnics that have better facilities in the country for the test of their construction materials. Even the road research institute in Ogun state in Nigeria can help if the facilities are adequate.

2.5.5.7 USE OF LOW QUALITY MATERIALS

According to Okigbo (2012), use of low quality aggregate adversely affects the quality of the roads. This sometimes occurs in the form of the improper grading of aggregates for sub base and poor sub grade soil. The use of extreme cohesive and expansive soil as sub grade soil results in prolonged

consolidation and unnecessary settlement of the roadway. The use of soil of low bearing capacity leads to the failure of the sub grade soil.

2.5.5.8 POOR WORKMANSHIP

According to Okigbo (2012), most of the workmen in construction sites are not well trained; especially, among the artisans and the craftsmen. Sometimes, the technicians, the technologists and even the engineers are not given adequate practical training. Inappropriate application of materials by the workmen is mostly due to low knowledge of the works by the workmen. Operations like soil compaction and stabilization are inadequately done due to low knowledge of the workers.

2.5.5.9 POOR SUPERVISION

According to Igomu (2011), most of supervisions of construction works may be done by untrained engineers and other middle level supervisors like foremen. Some of these supervisors who have low knowledge of the works find it difficult to deliver adequate supervision at the site. Some of the faults on the roadway like depressions, cracks and even potholes can occur due to improper workmanship that resulted from wrong supervision. Wrong supervision could result to improper application of the material and operation of the works. Operations like the application of bituminous material, compaction of the soil etc could be messed up because of improper supervision.

2.5.5.10 LOW KNOWLEDGE BASE

According to Okigbo (2012), lack of modern method of road construction on the part of the old engineers and low curriculum standards on the part of the young engineers are some of the problem of road construction in Nigeria. Even the multi-national construction companies in the country, their workers display inadequate knowledge of the process of road construction. There are modern methods and standards of road design and construction available today. Our road contractors have to avail themselves of the use of these available new and modern methods of road construction and maintenance.

2.5.5.11 INADEQUATE SANCTIONS FOR HIGHWAY FAILURES

According to Okigbo (2012), there have been records of failures on Nigerian highways. No body or agency has ever been held responsible. Even the roads constructed by the multi-national companies, some of them start failing before the construction work are completed. Even when accident occurs, it is generally blamed on the behavior of the driver without looking at the effects of the nature of the road. The main factors that contribute to the causes of accidents are driver behavior, nature of

vehicle and the nature of the road. In Nigeria whenever accidents occur, we emphasize the driver behavior while deemphasizing the effects of the other factors which make tremendous contribution to the cause of accidents.

2.5.5.12 CLIMATIC CHANGES

Zumrawi M.(2016) raised climatic factors include rainfall and annual variations in temperature that are important considerations in road pavement deterioration. Rainfall has a significant influence on the stability and strength of the pavement layers because it affects the moisture content of the subgrade soil. The effect of rain on road pavements can be destructive and detrimental as most pavements are designed based on a certain period of rainfall data. In addition, rainfall is well established as a factor affecting the elevation of the water table, the intensity of erosion, and pumping and infiltration (Khaing and Htwe, 2014). Long periods of rainfall of low intensity can be more adverse than short periods of high intensity because the amount of moisture absorbed by the soil is greater under the former conditions (Sargious, 1975). He further emphasized that water is the critical factor that cause road failures. Once water has entered a road pavement, the damage initially is caused by hydraulic pressure. Vehicles passing over the road pavement impart considerable sudden pressure on the water, this pressure forces the water further into the road fabric and breaks it up. This process can be very rapid once it begins. When vehicles pass over the weak spot, the pavement will start to crack and soon the crack generates several cracks. Water will then enter the surface voids, cracks and failure areas. This can weaken the structural capacity of the pavement causing existing cracks to widen. Eventually, the water will descend to the subgrade, weakening and hence lowering the CBR value of the subgrade on which the road pavement design was based upon.

Wee and Teo (2009), reported that climatic changes in temperature and rainfall can interact together. Rainfall can alter moisture balances and influence pavement deterioration while the temperature changes can affect the aging of bitumen resulting in an increase in embrittlement of the bitumen which causes the surface to crack, with a consequent loss of waterproofing of the surface seal.

2.5.5.13 POOR DRAINAGE

The highway drainage system includes the pavement and the water handling system which includes pavement surface, shoulders, drains and culverts. These elements of the drainage system must be properly designed, built, and maintained. When a road fails, inadequate drainage often is a major factor. Poor design can direct water back onto the road or keep it from draining away. Too much

water remaining on the surface combine with traffic action may cause potholes, cracks and pavement failure (Zumrawi , 2016).

Abhijit et al. (2011), investigated the effect of poor drainage on road pavement condition and found that the increase in moisture content decreases the strength of the pavement. Therefore, poor drainage causes the premature failure of the pavement. Little and Jones (2003), further investigated moisture damage in asphalt pavements due to poor drainage. They found that the loss of strength and durability due to the effects of water is caused by loss of cohesion (strength) of the asphalt film, failure of the adhesion (bond) between the aggregate and asphalt, and degradation of the aggregate particles subjected to freezing.

Moisture damage generally starts at the bottom of an asphalt layer or at the interface of two asphalt layers (Khosla et al., 1999). Eventually, localized potholes are formed or the pavement ravels or ruts. Surface raveling or a loss of surface aggregate can also occur, especially with chip seals. Occasionally, binder from within the pavement will migrate to the pavement surface resulting in flushing or bleeding (Stuart, 1990).

2.5.5.14 EXPANSIVE SUBGRADE SOIL

Zumrawi M. (2016), raised expansive soil as road subgrade is considered one of the most common causes of pavement distresses. Longitudinal cracking results from the volumetric change of the expansive subgrade, is one of the most common distresses form in low volume roads. This type of cracking is initiated from the drying highly plastic subgrade (PI >35) through the pavement structure during the summer. Other forms include fatigue (alligator) cracking, edge cracking, rutting in the wheel path, shoving, and popouts. Figure 2-1 below illustrates expansive subgrade effect.

Figure 2- 1: Expansive subgrade effect

2.5.6 ROAD MAINTENANCE BUDGET AND INSTITUTIONAL CAPACITIES

The main source of funding for road infrastructure in developing countries has traditionally comprised direct government allocation, through Public Sector Investment Programmes (PSIP), vehicle licenses and fuel levies. However, Mbara et al. (2010), raised on their study paper of

"Challenges of Raising Road Maintenance Funds in Developing Countries" the paucity of funds from these sources, governments are increasingly considering applying the road-user pay principle, which involves motorists paying a fee (toll) for driving on a particular road. An ideal implementation of this principle prescribes that road users need to have the option of using alternative transit routes, to fulfill the requirement for choice and fairness in infrastructure provision. For countries in the developed world that have introduced road tolling, the strategy was meant to generate revenue for road infrastructure financing and to control traffic flows through demand management.

While road sector reforms have focused on maintenance, there is evidence of a persistent capital bias in spending. Investment accounts for two-thirds of total spending, leaving only one-third for maintenance. Based on practice elsewhere in the world, the balance between investment and maintenance should be closer to half and half (Ken Gwilliam, 2008). The capital bias is most pronounced in low-income countries, those with difficult geographical environments, and those without road funds or fuel levies, which may in part explain the higher levels of spending observed in these countries.

As also, stated by Burningham and Stankevich (2005), maintenance costs vary with road conditions, traffic volume, geographic location, climatic conditions, work methods, technical equipment and other factors.Where no maintenance program is in place, cost calculations do not have to be precise at the beginning. The Authors further stated that the main point is to get started. If calculations of road maintenance need using sophisticated road management systems or complicated formulas seem overwhelming, start with simple rules of thumb.

It is therefore important to consider the cost of maintenance when planning a route or investment in part of that route, setting appropriate standards and specifications for the road and the approach to contracting and procurement. On lower category roads, the involvement of the local community or stakeholders can substantially reduce the operational and overhead costs. At the initial planning stages, the 'whole lifetime costs of the road should be considered as an integral part of the design process - not just the short-run capital costs of the initial construction, but also the long-term costs of its maintenance. A realistic assessment of the capability and likelihood of timely road maintenance will be a major influence on the effectiveness of the construction investment. The document Priorities in Improving Road Maintenance Overseas: a check-list for project assessment is a useful guideline to support assessment of maintenance capability (World Bank, 2014).

Frequently, problems arise because the road maintenance costs have either been underestimated, or insufficient financial provision has been made for them. The World Bank's Road Costs Knowledge

System (ROCKS) provides a source of knowledge on the cost of road maintenance and rehabilitation for different types of road, drawn from different regions. Maintenance can be achieved at lower costs using innovative local-resource-based approaches. Once a maintenance program is in place, road maintenance needs can be estimated more accurately through direct or indirect assessments according to Burningham and Stankevich (2005):

- A direct assessment can be based on the output of a standardized road management system such as the World Bank's HDM-4 (WB HDM-4 website). The road agency needs strong technical capacity to operate such models and to modify them appropriately in calculating costs for sub-national level roads.
- An indirect assessment uses formulas related to road length, traffic, and other variables affecting maintenance needs. This approach requires less technical capacity than the direct assessment approach. Estimates can be based on available average maintenance costs per kilometer for different types of road.

To react how to ensure a steady flow of maintenance funds question; good maintenance requires a steady and reliable flow of funds. Burningham and Stankevich (2005) said that there are several reasons why this often fails to materialize. Those responsible for allocating the budget may have little understanding of the economic and social importance of maintenance; they may have allowed the budget process to become politicized, favoring construction, which is more visible and popular, over maintenance; or they may believe that fiscal constraints justify deferring maintenance, which only raises future costs. Burningham and Stankevich (2005), put several ways to address these problems:

- Rely on a single annual allocation from the national budget to the road sector, with the road agency responsible for allocating appropriate funds for maintenance. This only works where the road agency recognizes the importance of maintenance and is not under pressure to prioritize new construction.
- Create a ring-fenced road maintenance line item in the national budget. The ministry of finance would thus be responsible for the allocation. This is not always a secure and stable financing source, but it has the advantage of being designated under the budget law.
- Set up a dedicated road fund that receives resources directly from road user charges. The road fund can be included in the budget or it can be off-budget and managed by an independent road fund board established by relevant ministries and road user associations. Sometimes road funds accumulate too much money, which can encourage spending on new roads, which may not be in the national interest.

- Give the road agency more discretion in concession of maintenance activities to private sector providers, which could be allowed to charge tolls to cover the cost of maintenance. This option could be combined with any of the other options.

Therefore, the cost of road maintenance can also be reduced by better evaluation of condition, prioritization of works, improved contracting or by the use of more innovative approaches such as labour-based or community contracting in remote or rural areas, or by the use of performance-based contracts.

2.5.7 CONTRACTING PARTY OF ROAD MAINTENANCE

"Ethiopia has experienced strong economic growth and has achieved substantial progress on social and human development over the past decade," said Guang Zhe Chen, World Bank Country Director for Ethiopia. "Upgrading and maintaining the country's road sector is an important part of our work in Ethiopia. Today's project will help to enhance trade, create new markets, and provide improved access to education, medical services, and food security to the country" (World Bank, 2014). During the GTP II period covering 2015/16 to 2019/20, the GOE anticipates a further expansion of the country's road network to 220,000 kilometers (136,701 miles). In the past, U.S. firms have bid on tenders for road design, construction and supervision services. However, most of them have not been price competitive. Ethiopia will continue to need construction vehicles (bulldozers, cranes, trucks, and forklifts), vehicle attachments, and mechanized and non-mechanized equipment to level and pour construction materials. Most projects open for international competitive bidding are funded either by the GOE or major international financial institutions, such as the World Bank's International Development Association (IDA) and the African Development Bank (AfDB) (GOE, 2017).

What types of contractors could be used in road maintenance? To answer these question, Burningham and Stankevich (2005), raised Routine maintenance contracts are often short term (6–12 months) and low value, with little appeal to contractors from other countries. Many countries therefore use domestic contractors to implement maintenance works. A strongly developed local contracting sector has several advantages, from works methods tailored to local conditions and improved productivity to greater accountability and lower cost. The creation of direct and indirect employment opportunities also contributes to poverty reduction. They further stated on aspects of effective contracting include efficient designs informed by local knowledge, use of local contractors and consultants, generation of local employment and income, capacity building, use of appropriate technology, and simplified contract forms. In addition, effective contracting requires:

- Capacity to prepare bid documents, arrange contracting procedures, process contracts, supervise work, and deal with arbitration issues.
- Straightforward procurement procedures. Use of procurement is strongly recommended.
- A steady flow of funds to pay contractors.
- A quality assurance plan developed in close collaboration with quality control engineers that assigns clear responsibilities to contractors, consultants, and road agency and spells out expected road maintenance outcomes for contractors and technical audits for consultants.

Furthermore, Burningham and Stankevich (2005) stated that private contractors are increasingly being used in place of in-house units, for reasons of cost-effectiveness and efficiency. Claims that in-house units are cheaper are often based on improper costing of the force account activities. Maintenance activities are easy to learn, so that a system that combines microenterprises for routine maintenance and larger contractors for periodic maintenance can be established quickly. Redundant force account crews—and their equipment—can be reorganized to become contractors, with some training and supervision. They should not be retained as agency staff. However, the same firm contracted to do routine maintenance can also handle emergency work. If maintenance is carried out regularly and properly, the need for emergency work will reduce substantially. A limited number of in-house units can be retained to allow emergency work under force-majeure circumstances, such as earthquake and flooding (Burningham and Stankevich, 2005).

Road maintenance in South Africa's entire national road network is covered by routine road maintenance contracts. A managing contractor is paid a fee to manage the work of historically disadvantaged enterprises and micro, small, and medium-size enterprises, which perform 80% of all maintenance work. This system ensures that the entire national road network is maintained by contractors responsible for maintenance and any emergencies that arise (SANRAL, 2004). Road maintenace contractors can be classified by size of contract and type of work (TRL and DFID, 2003):

- **Length-worker**: an individual contracted to perform routine maintenance on a 1–2 km road section. The length-worker often lives alongside the road and is supplied with tools and material. Since managing individual length-workers is inefficient, they can be encouraged to join into small contracting organizations or to subcontract to larger contractors.
- **Community contractor**: an organization that springs up in response to emerging community needs and may then dissolve again the need is met. Any profits are returned to the community to fund future maintenance needs. Most activities in which they engage are labor-

based or labor-intensive. This type of arrangement provides employment to the local population.

- **Petty contractor**: like a community contractor, uses labor-intensive methods and performs routine maintenance works in a very local area. Can be a cooperative with some 10–20 members with limited technical qualifications. Differs from a community contractor in being a private organization.
- **Microenterprise**: a cooperative or community association set up as a private enterprise and operating likes a petty contractor.
- **Small scale contractor**: usually operates only in a local area, but strives to grow in size, technical capacity, and geographical range. Small-scale contractors are trained in labor-based methods and are competent to work on unsealed roads only. They have more technically qualified staff than a microenterprise.
- **Medium- and large-scale contractors**: may begin as a small-scale contractor or as a merger of several small contractors. A medium-scale contractor often has more sophisticated equipment and wants to use that investment as much as possible. Its staff is often trained in new skills, such as the construction of improved and bituminous surfaces. A large-scale contractor operates nationally and, possibly, internationally and is interested in large, area wide, multi-year performance contracts, possibly subcontracting some activities to small contractors.

Abdulkareem and Adeoti (2010) on their study of "Road Maintenance and National Development", discussed the various approaches to road maintenance over the years so as to acknowledge the efforts of government. The approaches to execute maintenance work is based on the two methods as follows:

- **Direct Labor Maintenance:** The agency undertakes the repair through their work force, equipment and procurement of maintenance materials.
- **Maintenance by Contract*:*** The services of reputable contractors having asphalt plants, necessary equipment and manpower are engaged. The supervision is done by the client or through consultants engaged by the-clients. This sector is presently dominated by foreign multinational executing about 85% of road construction, rehabilitation and maintenance.

Therefore, options for maintenance can vary widely according to the type of road and by the type of contracting and procurement systems chosen. There has, for example, been some excellent work carried out to develop labour-based, local and community contracting but the experience has shown that this approach, whilst cost-effective, needs careful planning and usually the oversight and support

from road management organizations if it is to be sustained in the long-term. The labor-based 'length-man' system has been used in various forms in many countries. However, the system is dependent on a consistent provision of funds and supervisory support. If this is withdrawn for a period of time, the consequential backlog of work can overwhelm the system and necessitate expensive, large scale rehabilitation (Oladele and Egwurube, 2011).

2.5.8 EFFECTIVE AND EFFICIENT ROAD MAINTENANCE

According to Mohamed (2010), the effectiveness of a maintenance system or work can be assessed through the performance of structure before and after maintenance. The best person to do the assessment will be the users themselves because only users will feel the differences and therefore can comment on the performance of the specific structure. And further, Mohamed (2010) considered achieving effective and efficient maintenance as follows:

- **Function of maintenance*:*** Maintenance works are done to achieve desired goals determined during stages with the main functions in maintaining the roads in a condition that gives good service and maximum safety to the travelling public. This is achieved by keeping the road free of disconcerting physical defects such as potholed pavements, broken pavement edges, loose gravels, stick surfaces, loose and defective bridges decks and other imperfections.
- **Value of maintenance*:*** the actual value of maintenance is building or any other structure that will last longer with proper and continuous maintenance. Poor maintenance may result in the need for reparation, renovation or reconstruction, which will increase in cost at the end of life cycle of the structure. The value of maintenance is discussed from the aspect of:
    - ✓ **Time:** Compared to time required for reparation and renovation on a structure, maintenance consumes less time, but can produce better quality results. Besides, work qualities for maintenance are also relatively lesser compared to reparation and renovation.
    - ✓ **Cost:** The costs required by maintenance are lesser than cost required to repair or to rebuild a structure. Furthermore, a specific structure can still be running under maintenance hence saving cost from the economic perspective.
    - ✓ **Structure value and performance*:*** Structure will have high value and good performance during its service life, if maintenance works are done according to schedule and plan. Without proper maintenance, a structure will not be able to provide services at its maximum performance all the time.

Ajijo and Ambo (2005) raised in "A Project Completion Report on Road Maintenance and Rehabilitation Project in Ethiopia", that the project was implemented through Force Account Unit of ERA. Many problems and difficulties were encountered during implementation that accounted for a large part of the slippage in the overall completion. The project, which should have been completed in three years continued up to eight years for final completion. Some of the major factors that contributed to this long slippage are given hereunder (Ajijo and Ambo, 2005):

- Frequent suspension of construction works due to conflicts in the project area;
- Non-deployment of adequate construction equipment/machinery on site;
- Delay in procurement of construction machinery and consequent delay in its supply coupled with non-availability of spare parts on time during frequent breakdowns;
- Non-availability of construction materials and water in the vicinity (it involved long hauling distances);
- Extreme bad weather conditions with day temperatures ranging from 45 to 50 degrees centigrade during most part of the year, which restricted the working hours of the personnel that virtually retarded the progress and efficiency of the Force Account Unit personnel;
- Frequent changes in the deployment of the Project Manager and other personnel coupled with improper coordination;
- Existence of flood prone area on the re-alignment section at Dobi depression;
- Delay in initial review of the design and its effect on the commencement. This accounted for a large slippage in the implementation.

To be sure that road maintenance is not neglected; it needs to be incorporated into project and sector strategies. That requires a clear and realistic strategy for road network management that attends to the following key principles according to (Burningham et al.,2005),:

- **Use the core network concept** as a rule of thumb, 80 percent of traffic flows over 20 percent of the road network. This core network is often the responsibility of the national government's highways ministry. These most heavily jammed roads should receive priority for full routine and periodic maintenance.
- **Clearly assign to specific institutions "ownership"** of roads and responsibilities for development, maintenance, and priority-setting. Often, when construction or upgrading has been completed by the national road agency through a loan or grant, responsibility for maintenance remains unclear or is handed over to the "community." Good practice indicates that the agency that implements the road construction or rehabilitation be responsible for subsequent routine and periodic maintenance.

- Involve all agencies and institutions associated with roads at national, regional, district, and local community levels as well as road users and other stakeholders in identifying road issues and planning road interventions. Other stakeholders include organizations dealing with tourism, health care, rural development, agriculture, and mining; road user associations; community organizations; nongovernmental organizations; and businesses.
- Determine the overall level of funding required and the balance among construction, rehabilitation, and maintenance. Priority for maintenance funds should go to roads that are functionally important and in reasonably good condition. Routine maintenance should be included as a cost component in donor-funded road construction projects even if maintenance is fully funded by government resources, to ensure that it is not neglected.
- Develop standards for improving roads: Design standards and maintenance practices should be reviewed to ensure the sustainability of the entire road network. For instance for low-volume roads, design standards may stress accessibility and durability rather than width and speed.
- Include maintenance of bridges, road signs, sidewalks, and other road structures. Neglected road structures and signs lead to increased road accidents and, in the case of bridge deterioration, can lead to road closures and network disruptions.
- Assess capacity to fund, manage, and supervise road maintenance**:** International donors have become increasingly involved in road maintenance programs, and this can be good if temporary solutions are provided for some road agencies. For the longer term, donors should help to create a more stable source of funds.
- Assess the capacities of municipal, district, and provincial road agencies to perform any management and supervision responsibilities delegated by the central road department.
- Define objectives and develop plans for road maintenance capacity building, including training, technical assistance, and local revenue generation.

2.5.9 ECONOMIC AND INSTITUTIONAL ASPECTS IN ROAD MAINTENANCE

Harral Clell (1988), studied on "Road Deterioration in Developing Countries: Causes and Remedies"; raised that the condition of unpaved roads in countries with newer paved roads differs little from that in countries with older paved roads. So, the state of a country's paved roads, by itself, says little about the country's maintenance capacity. In many countries, the rapid expansion of networks has outstripped the growth in institutional capacity for road maintenance. Prolonged under-maintenance, however, can eventually result in a net diminution of the road network.

Further stated by Harral Clell (1988), "technical options and their economic consequences of road maintenance"; economic decisions about a highway system must take into account the total cost of transport on the roads: the discounted life-cycle cost of constructing and maintaining the roads and the (usually) far larger cost of operating vehicles on these roads. These costs must be estimated on the basis of sound knowledge about road and traffic conditions and the interactions between them, as well as the applicability of different maintenance techniques in different environments.

Experience has provided no standard solutions to the problems of institutional performance. Without proven formulas, institutional development has had to proceed by continuous, local experimentation. Experience has, however, identified constraints on improved performance and some general principles worth pursuing (Harral, 1988). Ther following three factors have worked against the development of effective institutions for road maintenance (Harral, 1988):

- The nature and constitution of the typical road agency. Most road authorities have conflicting objectives and functions and therefore operate under incompatible incentives;
- The weak public pressure for better roads; and
- The inadequacy and unreliability of funding.

Teravaninthorn et al. (2014) stated promoting decentralized road development in the transport ector development in Ethiopia. Transport sector development in Ethiopia is the responsibility of the Ministry of Transport (MOT) and the Ministry of Urban Development and Housing Construction (MUDHC). Road sector development and maintenance is mainly executed by the Ethiopian Roads Authority (ERA), Regional Roads Authorities (RRAs), Municipal Road Authorities (MRAs) and the Woreda Road Desks (WRDs). ERA is also responsible for road sector policy, overall network planning, road development and coordination in the country.

The Transport Authority is responsible for regulating transport services, including vehicle registration and licensing. Federal Roads, accounting for 25,756 km of the total road network, are maintained by ERA and the remaining 32,582 km and 27,628 km of rural roads (all unpaved) and the Universal Rural Roads Access Program (URRAP) roads respectively, generally fall under the Regions. Urban roads are maintained by the respective MRAs, while Addis Ababa and Dire Dawa have independent road authorities responsible for road administration.

The responsibility for the preparation of road safety strategies and programs; the coordination of government and nongovernmental organizations; and the promotion of road safety awareness nationwide lies with the National Road Safety Council (NRSC) which reports to the MOT. The Federal Traffic Police (FTP) are responsible for the enforcement of traffic regulations and transport infrastructure is a key requirement to promoting economic development. The proposed project is

seen to support the core pillars of the "New Africa Strategy", which are focused on: improving competitiveness and employment and addressing vulnerability and promoting resilience (Teravaninthorn et al., 2014).

How should road agencies engage with the ministry of finance and present annual maintenance budgets? Burningham and Stankevich (2005) discussed on their study to answer this question. Road agencies need a system for requesting budget funds, and they need accountability and audit mechanisms to account for the funds' use. Some funding sources are satisfied with a single, total figure, while others demand more detailed information, including work methods and technology choice. Routine and periodic maintenance costs may need to be separated. Enough details should be provided to permit later auditing against planned works. The budget may include such additional costs as overhead and contingencies for inflation and emergency works. Provisions for inflation are important in contracts of longer than a year and in short-term contracts in countries where inflation is high.

They further discussed the funding and source allocation following standard procedures. When funds are allocated by the ministry of finance, the road agency's requests would be assessed against those of other sectors as well. Other factors influencing funding decisions include quality of submission, network size, historical precedent, and technology choices. When regional and local level agencies depend on transfers from the central government, the ministry of finance determines the allocation for the entire road sector.

Accountability mechanisms are also important. National treasuries are reluctant to release funds unless road agencies can demonstrate how the funds are used and with what effectiveness. Again, strong support from political leaders and national treasuries is crucial. A road board and road fund will not achieve the desired results unless there is a strong political will to support those (Burningham and Stankevich, 2005).

2.5.10 ROAD MAINTENANCE PROCEDURES

With road costs rising, it is more important than ever that engineering standards should be cost-effective. Network analysis reveals that on average around 30 percent of main road networks are over-engineered relative to observed traffic volumes, while only 10 percent of main road projects (and 15 percent of rural projects) are under-engineered. The failure to follow appropriate engineering standards suggests that resources have been wasted, but it also points to the way to cost savings in the future (Ken Gwilliam, 2008). During a long initial phase that lasts up to two thirds of their life

cycle, paved roads undergo little visible deterioration. This is followed by a phase of increasing-and increasingly rapid-deterioration (into fair condition) that ends within a few years in radical structural failure (poor condition) (Harral, 1988). This nonlinear path of deterioration affects the choice of the optimal maintenance policy for paved roads. For the unwary it also tends to disguise the future maintenance requirements of young networks.

Harral (1988) further explained during the first phase a paved road can be kept in good condition with fairly inexpensive routine maintenance. In the subsequent phase of increased deterioration, the pavement can be restored to good condition by resurfacing or, at a moderate cost, by adding an overlay. An overlay will restore the ride quality of the road, make the pavement strong enough to meet traffic requirements for the next several years, and thus start a new pavement cycle. With adequate routine maintenance and timely resurfacing or strengthening, a paved road should not deteriorate into poor condition or require reconstruction.

Developments are continually being made to the available technology, materials and approaches to maintenance. In recent years, there has been increased interest in the use of marginal or non-standard materials, recycling and local materials in road maintenance. These and other innovations in road and vehicle technology are also covered in the sections on technology and standards and specifications (Oladele et al., 2011). Oladele and Egwurube (2011), on their paper of "highway maintenance cost estimation modeling for developing countries" highway pavements during a typical design life consist of four basic stages in relationship to maintenance as stated below:

- **Stage I:** Early in a pavement life, preventive maintenance is needed to retard the normal aging process, prevent the intrusion of water, and improve skidding resistance. Typical preventive maintenance activities are surface rejuvenation, crack sealing, seal coats, and spill repairs.
- **Stage II:** As a pavement is subjected to significant traffic and the aging process continues, sufficient distress occurs to warrant corrective maintenance activities riding surface, provide adequate drainage and retard the failure of the various pavement layers. Some corrective maintenance activities include: correction to shape, patching, resurfacing. The need for these corrective maintenance activities can often be delayed if proper preventive techniques are applied.

- **State III:** When significant corrective maintenance activities are needed on a pavement, it is generally time to begin programming a minor rehabilitation project in a timely fashion – 2-4 years – for the section, depending on traffic and degree of deterioration.

- **Stage IV:** Maintenance activities delay the need for rehabilitation, but cannot be expected to adequately deter acceleration for long periods of time. A stage will be reached when the pavement will need to be strengthened. This is an inevitable level. This stage retrospectively defines the service life of the original pavement.

More recently, the Transport Research Laboratory (TRL) produced Overseas Road Note 18: A Guide to the Pavement Evaluation and Maintenance of bitumen-surfaced roads in tropical and sub-tropical countries. The Overseas Road Note 20, Management of Rural Road Networks, provides further guidance. The World Bank (1990) implied the wide lack of systematic and appropriate road maintenance in developing countries which is mainly a result of a lack of funds and undeveloped maintenance organization. Only recently has the importance of systematic monitoring, network evaluation and regular maintenance works become generally recognized. The World Bank (1990) further stated that regular and reliable information on road condition is essential for managing the maintenance of a road network, both for assessing the physical and financial needs and for evaluating the effectiveness of road maintenance practices. Certain maintenance activities are performed routinely (normally at intervals of one year or less) and these are defined as routine maintenance. Other operations are performed less frequently (intervals of more than one year) and are periodic maintenance. A third type of maintenance activity, urgent or emergency maintenance should be carried out immediately upon identification. The World Bank (1990) mentioned that there are two principal management applications and these are:

i. **Maintenance management:** the aim is the efficient organization, scheduling, and budget-control of maintenance activities within the budget or fiscal year; in formal systems, this often includes assessment of the effectiveness of the works and the productivity rates; and
ii. **Pavement management:** a planning and programming procedure – that minimizes the whole lifetime cost of the road and requires information on the condition and trafficking of the pavement, to evaluate and schedule appropriate major maintenance or rehabilitation works, in both medium-term plans and yearly programmes.

Burningham et al. (2005) raised that maintenance operations can be outsourced to private organizations or carried out using force accounts (in-house units and equipment). Responsible road agencies need competent maintenance program management, a good monitoring system, and clear and transparent procurement procedures. Procedures for contract management vary, but most have these four steps: invitation for bids; Assessment of bids and contract award; Management of ongoing contract; and Auditing and evaluation of completed work.

Zumrawi (2015) on survey and evaluation of flexible pavement failures; established guidelines for inspection and evaluation of pavement failures and to find out the possible causes of these failures. Some of the basic steps are the following:

- Inspection and Evaluation plan;
- Documents and literature review;
- Pavement condition survey;
- Experimental work;
- Determine probable cause(s) of failure;
- Select the best maintenance option; and
- Report on outcomes.

2.6 MAINTAINED ROAD CONDITION

In 1988, the GOE as a part of its policy, embarked on restoration of road network through rehabilitation and maintenance activities. Given the country is landlocked, in order to facilitate transportation of goods to the nearest ports of the neighboring countries that handle more than 85% of foreign exchange trade, the GOE accorded priority for maintenance and rehabilitation of deteriorated road sections (Ajijo and Ambo, 2005). In every maintenance situation, safety and accessibility are important considerations for everyone involved including the drivers who use the roads. The impact of these operations on highway maintenance process must accommodate the ever-present effect of traffic (Oladele et al., 2011).

2.6.1 CAUSES OF REGULAR FAILURES OF MAINTAINED ROADS

According to Wada and Surajo (2016), maintained bituminous pavement deterioration generally takes place due to combined action of traffic, weather changes, drainage, environmental factors etc. Flexible pavements generally deteriorate at a very rapid rate when compared to rigid pavements due to the above factors, however, flexible pavements continue to deteriorate at a slow rate even without the traffic movement on the surface due to the climate and environmental factors (Khanna et al,. 2014).

Harral (1988) raised three facts on maintained road deterioration to clarify the problems as follows:

- First; because reconstruction costs are three to five times as much as resurfacing or rehabilitation, no road should be allowed to decline into poor condition unless it is to be kept in that condition deliberately (with routine maintenance but no resurfacing or rehabilitation) or abandoned entirely.

- Second; normally there is a period of about five to eight years during which paved roads in fair condition can be restored by resurfacing or strengthening. After that time, more costly measures become necessary. The existence of many roads in fair condition suggests that extensive maintenance is needed quickly if roads are to be saved before declining to poor condition.

Third, the costs of operating vehicles (especially large trucks) rise as roads deteriorate. This is because, vehicle operating costs are the largest part of transport costs. In order to examine methods of highway maintenance, Abdulkareem (2010) stated that the causes of structural failure must be defined and analyzed so that remedial measures will prevent, reduce or correct these failures. The main causes of deterioration resulting into failures of a road pavement are: the action of traffic with heavy goods vehicles having the greatest detrimental effect; the action of weather, rain and heat; unstable ground conditions and poor drainage; types of construction materials and methods; post construction activities like, digging of trenches along the road. Dumping of building materials and other obstructions on the road, uncontrolled street trading etc.; poor workmanship; and inadequate maintenance.

Rate of deterioration of maintained bituminous pavement increases rapidly when water is retained in the void spaces of the bituminous pavement layers. Aging and oxidation of bituminous binder also lead to the deterioration of the bituminous surfacing (Wada and Surajo, 2016). Many researchers generated several parameters/factors of maintained road deterioration. Among them, Wada and Surajo (2016) considered the following factors: traffic loads, subgrade soil, climatic factors, pavement component materials, drainage and environmental factors. They further stated the types of bituminous pavement deterioration as: surface deformation, cracking, disintegration, and surface defects.

2.6.2 FACTORS AFFECTING MAINTAINED ROADS

According to Oladele & Egwurube (2011), maintained road has been long recognized that those who design highways have given inadequate consideration to the maintenance problems that are related to many designs. Aging facilities, greatly increased traffic volumes, tighter budgets, and limitations on staff have only served to compound the problems associated with maintenance. It must be appreciated that no matter how well designed and constructed, maintained pavement deteriorates with age and use, and the engineers need to identify the type of deterioration. The main cause of deterioration and resulting failure of a maintained paved road are as follows (Oladele & Egwurube, 2011):

- The action of traffic, with heavy goods vehicles having the greatest detrimental effect;

- The action of weather, i.e. rain, and heat;
- Unstable ground conditions, or poor drainage;
- Post constructional trenches in bases and surfaces; etc.

2.6.3 FEASIBILITY OF TRANSPORT COST

A growing literature shows that there are significant and positive benefits of transport infrastructure for development. However, research on the cost side lags behind so that little is known about differences in the cost of infrastructure that countries face. Martina and Berger (2013), identified the following:

(i) there is a large dispersion in unit costs for comparable road work activities;

(ii) after accounting for environmental drivers of costs such as terrain, ruggedness and proximity to markets, residual unit costs are significantly higher in conflict countries;

(iii) there is evidence that costs are higher in countries with higher levels of corruption;

(iv) these effects are robust to controlling for a country's public investment capacity and business environment; and

(v) higher unit costs are significantly negatively correlated with infrastructure provision..

Shiferaw, (2011), evaluated the effect of two Road Sector Development Programs during 1997-2009 in Ethiopia and found out that improved road accessibility increases value added per worker. Khandker, (2009), found out that Bangladesh's Rural Development Project and the Rural Roads and Markets Improvement and Maintenance Project led to poverty reductions of 3-4% and 5-6%, respectively. Further, Buys (2010) used a subset of 465 road contracts in Sub-Saharan African countries from the ROCKS database to argue that upgrading of the roads network could lead to an expansion of trade by USD 250 billion over 15 years, at a cost of USD 20 billion for upgrading and USD 1 billion annually for maintenance costs.

CHAPTER THREE

RESEARCH MATERIALS AND METHODS

3.1 INTRODUCTION

The purpose of research methodology is to provide a sound platform for the researcher to achieve the aim and objectives of the study.

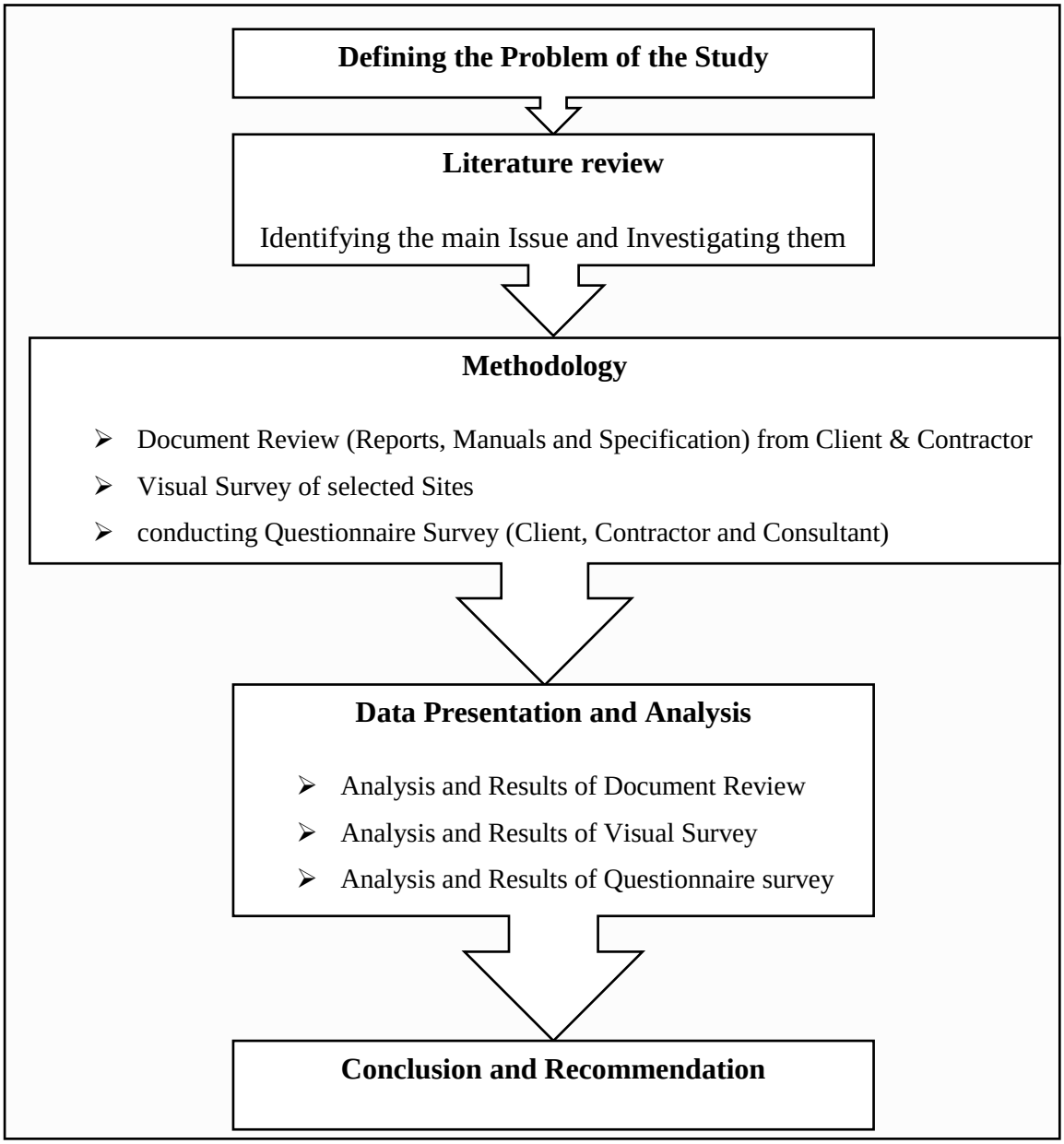


Figure 3- 1: Flow Chart of Research Process

This chapter deals with: research strategy; research design; research techniques; data collection procedures; data analysis and presentation methods. The key purpose of this chapter is to find answers to the research questions that emanated from the research problem. It examined the data collection instruments and how those instruments were employed in results generation. Therefore, data acquisition and analysis were meant to achieve the research objectives and then draw conclusions and forward recommendations based on the findings. Figure 3-1 shows that the research flow process.

3.2 RESEARCH STRATEGY

Generally, a research strategy is the approach in which the research objectives can be probed. Two types of research strategies are broadly employed and these are: quantitative and qualitative. Quantitative approach is used to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research accomplished previously. On the other hand, qualitative approach seeks to gain insights and to understand people's perception of "the world" whether as individuals or groups (Fellows and Liu, 1997).

Quantitative research was applied to understand the perceptions of clients, contractors, consultants and end users regarding factors affecting maintained paved Federal roads and frequent failure in Ethiopia. And qualitative research is selected to perceive the physical condition of maintained asphalt pavement road by taking photograph and visual survey.

3.3 RESEARCH DESIGN

Research design is the arrangement of conditions for the collection and analysis of data in a manner that aims to combine relevance to the research process with economy in procedure and it constitutes the blue print for the collection, measurement and analysis of data (Kothari, 2004). This study undertook a research survey which refers to the collection of information from a sample of individuals through their responses to questions. The research Survey was employed in order to obtain information that would describe the current condition of the Federal maintenance asphalt pavement roads and how road users are affected by frequent failures of maintained asphalt pavement roads. The survey involved; government institutions responsible for maintenance of roads, consultants who took part in the maintenance of the roads, the contractor that dealt with the maintained roads and maintained road users.

3.4 SAMPLING DESIGN AND SAMPLING FRAME

Sampling is concerned with the selection of a subset of individuals from within a statistical population to estimate characteristics of the whole population (Dillman , 2009). There are several compelling reasons for sampling, including; economy, greater accuracy of results and greater speed of data collection timelines and inaccessibility of some population elements (Nguru, 2008). Furthermore, the sampling procedure is determined by the purpose of the sampling and the parameters of the working population (Leedy and Ormrod, 2001).

Sampling frame refers to the source material or device from which a sample is drawn. It is a list of all those within a population who can be sampled, and may include individuals, households or institutions (McCabe, 2005). In many practical situations, the frame is a matter of choice to the survey planner, and sometimes a critical one. Some very worthwhile investigations are not undertaken at all because of the lack of an apparent frame, others, because of faulty frames, have ended in a disaster or in cloud of doubt (Dillman, 2009). The sample frame for this study included professionals from client, contractors and consultants that are concerned with maintenance of roads and their facilities and maintained road users.

3.5 SAMPLING TECHNIQUES AND SAMPLING SIZE

Random sampling is a technique used to ensure that every element in a sample frame has an equal chance of being incorporated into the sample. One of random sampling is cluster sampling which is useful when it is difficult or costly to develop a complete list of the population members or when the population elements are widely dispersed geographically. By using cluster sampling method, there are different sections with different networks coverage in Central District of ERA. In this research, one section facing more frequent failures of maintenance asphalt pavement road would be selected from each segment for data visual observation and analysis. Accordingly, cluster sampling had been used to select maintenance road segments as shown Table 3.1 due to large population elements is difficult, costly and time taking.

Random sampling includes choosing subjects from a population through unpredictable means. In its simplest form, all subjects have equal chances of being selected out of the population being researched (Chambers, 2003). This study used cluster sampling for visual observation-maintained roads from four areas within the Central region of ERA. Non-probability sampling is the case where the population is not entirely known; thus, individual probabilities cannot be known. Commonsense or ease is used to choose the sample, but efforts are made to avoid bias and keep the sample representative (Dillman, 2009). This had applied to respondents who used the maintained road.

Table 3. 1: Selected paved road network maintenance projects from Alemgena RNMD

S. No	Alemgena RNMD			
	RNM Project	**Road Segment**	**Length (km)**	**Selected length for observation (km)**

1	Debreberhan-Ataye road maintenance	Sembo-Debreberhan	40	1.5
2	Fitche-Gohatsion road maintenance	Comando-Fitche	7	1.5
3	Adama-Asela road maintenance	Adama -Melkasa	20	1.5
4	Addis-Modjo-Meki road maintenance	Modjo-Meki	59	1.5
5	Adama - Methara road maintenance	Welenchit - Methara	70	1.5

Source: ERA 2010 E.C.

Purposive sampling (also known as judgment, selective or subjective sampling) is a sampling technique in which researcher relies on his or her own judgment when choosing members of population to participate in the study. Purposive sampling is a non-probability sampling method and it occurs when "elements selected for the sample are chosen by the judgment of the researcher. Researchers often believe that they can obtain a representative sample by using a sound judgment, which will result in saving time and money" (Black, 2010).

The quantitative data collection samples were selected based on purposive sampling method from professionals who were working in client, contractors and consultants' offices working with ERA during the study period. This will ensure to collect reliable data from professionals. In total, there was one client, eight contractors and nine consultants. On the client side, eight individuals were included in the sample; on the contractors' side, sixteen individuals were selected and from the consultants, ten individuals were selected. The participants were identified by the representative of the respective organizations after explaining the objectives of the study. The total number of distributed questionnaires were: 12 to the client; 20 to contractors; 13 to consultants and 48 to concerned road users. However, the total number of responded and returned forms were 10 (83.33%), 16 (80%), 10 (76.92%) and 40 (83.33%) from the client, contractors, consultants and road users respectively.

3.6 POPULATION SIZE

Population is the total collection of elements about which one would wish to make some conclusions (Lapin, 1990). It is composed of the entire set of objects, events or people that can be studied (McCabe, 2005). In this research, the interest was in the working or study population. The

target population is that part of the general population that possesses the characteristics that the research aims to study, that is, fulfills the requirements of the research (Scheaffer, 1996). In this study the working population was classified into four groups; that included professionals from: the Client (ERA), contractors and consultants who were involved with road maintenance, maintained roads and road users.

The research focused on the professionals from the Central Road Network Maintenance District (RNMD) of Alemgena under ERA, contractors and consultants. The professionals from CRMND were chosen as the target population based on purposive sample for this study because they have the background knowledge on road maintenance and its performance. There were eight contractors. The data gathering in this regard especially focused on maintenance engineers at the Ethiopian Construction Works Corporation (ECWC) based on their experiences. Road users were also the target population of this study because they were directly affected by the frequent failures of maintained paved road.

3.7 DATA COLLECTION METHOD

Various techniques of data collection such as questionnaires, photographs, observation, interviews among others were employed in the study to obtain the information required in order to achieve the objectives. A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents (Gunilla Holm, 2008). Whereas, photography is the art, science and practice of creating durable images by recording light or other electromagnetic radiation, either chemically by means of a light-sensitive material such as photographic film, or electronically by means of an image sensor (Jeff Schewe, 2012). Photography provides a less biased recording than observations. Observation refers to the systematic identification of real-time processes or operations with the goal of investigating factors or improving processes and practices that is, what can be seen. Observations characteristically incorporate a prescribed protocol containing specific measures of observable behavior and the narrative recording of the program activities and their context (Lofland, 1995).

3.8 DATA COLLECTION INSTRUMENTS

Scheaffer (1996) highly recommended questionnaires as the most convenient and suitable instruments for both survey and statistical research. Scheaffer (1996) explains that the vast majority of survey samples involve very small fractions of populations and small increments in

the fraction of the population. Therefore, questionnaires, record files and observations were used as data collection instruments in this research work.

3.8.1 PRIMARY DATA

Questionnaires and site observation were used to collect primary data. Questionnaires were designed in two forms; one involving responses by government bodies, contractors and consultants in charge of road maintenance and the other involving responses from people who used maintained pave roads.

3.8.1.1 Questionnaire for Client/ERA

This questionnaire will be structured to be filled by government bodies in charge of maintenance of paved Federal road in Ethiopia. The main objective of this questionnaire is to identify the major causes for frequent failure of maintained roads and challenges experienced by the bodies mandated to maintain the Federal roads. In addition, it is required to understand the role of the contractors and consultants in maintenance of road, in case of the Central District of ERA, and the challenges experienced regarding frequent failures of maintained paved road.

3.8.1.2 QUESTIONNAIRE FOR CONTRACTOR/CONSULTANT

The questionnaire was filled by selected contractors and consultants; especially of ECWC who has worked for more than eight years on road maintenance. In addition to ECWC; there were seven contractors who have started since 2010E.C. on Federal roads maintenance. The main aim of this questionnaire was to know the cause of frequent failures of maintained roads based on their experiences.

3.8.1.3 QUESTIONNAIRE FOR MAINTAINED ROAD USERS

This questionnaire was structured to be filled by road users. The road users referred here include vehicle drivers through the sampled roads frequently, both public transport users and those using private vehicles. It was intended to understand how maintained road frequent failure has affected the conduciveness of the road users and how activities have changed because of frequent failure of maintained road.

3.8.1.4 OBSERVATION AND PHOTOGRAPHY

Observations were performed to understand the current operating conditions of maintained paved roads and compare against the acceptable standards. The research used a physical observation checklist which was filled through observations. Oral questions were asked to get more information and to clarify ambiguous perception of the visualization. A digital camera was used to take photographs of the current state of the maintained road. Table 3.2 below shows the Observation Checklist.

Table 3. 2: Observation Checklist.

S.No.	Observed maintained road distress	Road segments					Possible causes
		Sembo-Debreberhan	Comando-Fitche	Adama-Melkasa	Modjo-Meki	Welenchit - Methara	

Source: Field survey 2017/18

Photography is the way of data collection which was majorly used to capture the current status of the maintained road in selected road segments. It was meant to give a visual understanding of the research topic to the readers of this research work, the extent of worsening of maintained road condition.

3.8.2 SECONDARY DATA

Secondary data are the data that have been already collected by other researchers and are readily available from other sources; for example, published journals, articles and related websites. Secondary data is economical and time saving. It helps to make primary data collection more specific, this is because the researcher is able to identify the gaps and deficiencies and what additional information need be collected (Kosso, 2011). It also assists in understanding the problem as it provides a basis for comparison of the data that is obtained from the field.

In this research, secondary data were widely used. The data were obtained from reviews of relevant literatures pertained to road construction, road maintenance and its causes; contracting

party and the economic feasibility of national development. The literature used in this research was extracted from relevant books, journals, research projects and from internet websites.

3.9 DATA ANALYSIS AND PRESENTATION TECHNIQUES

Data analysis is conducted for the purpose of obtaining usable and useful information irrespective of whether the data is qualitative or quantitative. The research employed various statistical tools for analyzing the data collected from the field. The data were collected through the questionnaires and observational forms were converted into numerical codes representing measurement of variables using the Microsoft excel 2010.

Descriptive statistics - frequency tables and charts were developed to present a summary of the data by describing the type of data collected and its frequency and occurrence. Pictures were also used to clearly show some of the information captured through photography. The responses given by each respondent were calculated using the following average index formula:

$$\text{Average index} = \frac{\sum a_i x_i}{\sum x_i}$$

Where

a_i –constant that represent the weight of i

x_i-variables that represent the respondent frequency for i

i-1, 2…5

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 GENERAL

This chapter focuses on the results and discussion of data obtained from the archival review related to the Federal road maintenance, site survey/observation of maintained road and questionnaires. The data collected from the respondents and field study was discussed in order to achieve the objectives of this study.

4.2 RESULTS FROM DOCUMENT REVIEW

Through the review of documents, three-year annual reports, maintenance specification and maintenance manual were reviewed and assessed for the existence of maintained asphalt pavement road regular failures and the causes thereof in respect of completion time, estimated budget, contracting party, physical and social aspects and political implications. These data were collected by reviewing maintenance project documents of annual reports of contractors/ECWC, especially from Alemgena district.

Based on the results reviewed from three-year annual report documents, project name; fiscal year, planned budget, actual completion cost, rate of cost overrun of designated maintenance activities are presented in Table 4.1. Table 4.1 shows that actual cost more than budget implying that the assigned budget is not enough for maintenance design errors, scope change, inappropriate and inadequate procurement. In addition, Figure 4-1 illustrates the increase in the maintenance cost that is, the maintenance cost overrun was 138% in 2017 fiscal year.

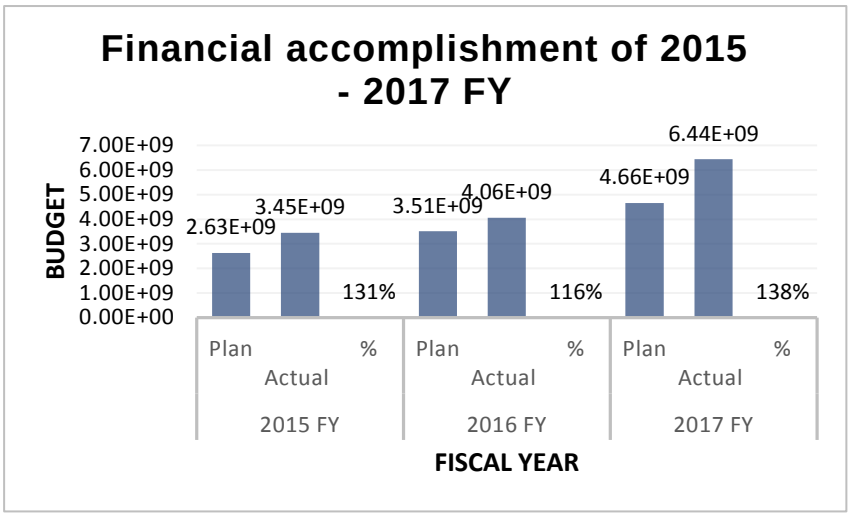


Figure 4-1: Maintenance cost overrun

Table 4-1: Road maintenance financial accomplishment report

Ethiopian Roads Authority										
Road Asset Management Projects										
2015 - 2017 FY Annual Financial Accomplishment Report										
No.	**Project Name**	**Financial Accomplishment**								
		2015 FY			**2016 FY**			**2017 FY**		
		Plan	**Actual**	**%**	**Plan**	**Actual**	**%**	**Plan**	**Actual**	**%**
1	**Routine Maintenance**	$3.77x10^8$	$4.85x10^8$	128%	$5.03x10^8$	$5.70x10^8$	113%	$6.17x10^8$	$9.05x10^8$	147%
2	**Periodic Maintenance**	$2.87x10^8$	$3.95x10^8$	138%	$3.82x10^8$	$4.65x10^8$	122%	$4.81x10^8$	$7.38x10^8$	153%
3	**Special maintenance**	$2.64x10^7$	$3.17x10^7$	120%	$3.52x10^7$	$3.73x10^7$	106%	$4.82x10^7$	$5.93x10^7$	123%
4	**Heavy Maintenance**	$1.53x10^9$	$2.05x10^9$	134%	$2.04x10^9$	$2.41x10^9$	119%	$2.81x10^9$	$3.83x10^9$	136%
5	**Paving Town Section**	$3.01x10^8$	$3.39x10^8$	112%	$4.02x10^8$	$3.98x10^8$	99%	$4.86x10^8$	$6.32x10^8$	130%
7	**Road Safety**	$1.14x10^8$	$1.49x10^8$	130%	$1.53x10^8$	$1.75x10^8$	115%	$2.19x10^8$	$2.78x10^8$	127%
Total		**$2.63x10^9$**	**$3.45x10^9$**	**131%**	**$3.51x10^9$**	**$4.06x10^9$**	**116%**	**$4.66x10^9$**	**$6.44x10^9$**	**138%**

Source**:** ERA, Road asset Management Project

Table 4-1 shows that the allocation of budget increased from 2015 – 2017 fiscal year. This explains that the deterioration of maintained road pavement increased i.e. the same road segment maintained in the same activity in the same year.

The Maintenance Projects' Completion Report show that the actual accomplishment of designated segments of road network under planned road length is presented in Figure 4-2 in percentages and details in Table 4-2.

The major factors adversely affecting smooth physical accomplishments are; poor maintenance management system, lack of competent contractors, poor budget allocation, road condition, terrain type, landslide, poorly established cost control system, unreliable source of materials on the local market and site accident, risk and uncertainty associated with projects, frequent design problems, dependency on imported materials, design change, cash flow and financial difficulties faced by the contractor, and fluctuation of materials costs, high labor cost, financial difficulties by client, poor contractor material handling, underestimation of the costs of projects, poor workmanship, etc. Figure 4-2 below illustrates paved road maintenance accomplishments in percentages as provided by the ERA.

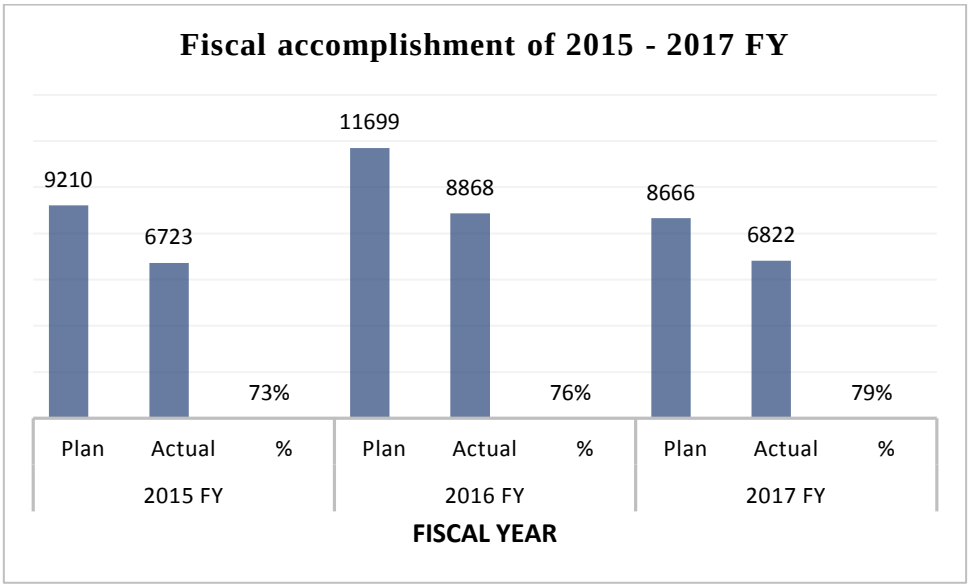


Figure 4-2: Road maintenance budget accomplishment

Table 4-2: Maintenance road network length

Ethiopian Roads Authority										
Road Asset Management Projects										
2015 - 2017 FY Annual Physical Accomplishment Report										
No.	**Project Name**	**Physical Accomplishment of paved road (length in Km)**								
		2015 FY			**2016 FY**			**2017 FY**		
		Plan	**Actual**	**%**	**Plan**	**Actual**	**%**	**Plan**	**Actual**	**%**
1	Routine Maintenance	6490.80	4815.12	74%	8113.50	6250.40	77%	6010.00	4808.00	80%
2	Periodic Maintenance	54.68	45.63	83%	60.75	52.65	87%	45.00	40.50	90%
3	Labor Base Maintenance (SME)	1933.31	1371.46	71%	2527.20	1861.70	74%	1872.00	1432.08	77%
4	Heavy Maintenance	565.58	385.48	68%	769.50	544.64	71%	570.00	418.95	74%
5	Paving Town Section	69.62	56.29	81%	79.84	67.04	84%	59.14	51.57	87%
6	Road Safety	95.54	57.00	60%	148.50	92.01	62%	110.00	70.77	64%
Total		9209.53	6722.56	73%	11699.29	8868.44	76%	8,666	6,822	79%

Source: ERA, Road asset management projects physical accomplishment.

Therefore, from the three-year annual report document, maintenance specification and maintenance manual reviews, the major causes of the frequent failures of maintained asphalt pavement Federal roads are summarized as follows:

- Shortage of equipment (asphalt distributer, pneumatic roller, excavator, dozer, shortage of asphalt paving equipment and chip spreader) and shortage of construction material (bitumen);
- Shortage of maintenance machinery (Grader, Roller, Damp truck);
- Delay in mobilization and poor site establishment by the contractor;
- Delay in production of stone for base course;
- Heavy rainfall in summer season;
- Contractor's inefficiency and incapability;
- Absence of separate crew for emergency;
- Capacity limitation of contractors;
- Frequent breakage of equipment;
- No sufficient manpower at the project site;
- Sites are handed over but no physical accomplishment yet;
- Planning and emergency works problems;
- Right-of-way problem for quarry sites;
- Delay in procurement;
- Construction materials supply problem; and

Therefore, the current situation is that the physical, social, economic and financial consequences of delayed maintenance are serious. Inadequately maintained roads prompt considerable loss of the original service, durability, capital investment, increased costs to road users due to: travel time delays, accidents in damaged vehicles, high costs of vehicle operations consequently slowing the overall economic development of the nation.

4.3 RESULTS FROM OBSERVATIONS AND PHOTOGRAPHS

The study has considered observation and photography as tools for data collection. These help to show the current state of the maintained subject roads in the central district of ERA at Alemgena RNMD. A few segments of maintained roads for which conditional surveys were taken are shown in Table 4-3 below. From the observations, a brief explanation of what was detected were captured with the help of photographs.

Table 4-3: Selected sections for condition observation

S. No	Alemgena RNMD			
	RNM Project	**Road Segment**	**Length (Km) of Paved Road**	**Selected length for observation (Km)**
1	Debreberhan-Ataye road maintenance	Sembo-Debreberhan	40	1.5
2	Fitche-Gohatsion road maintenance	Comando-Fitche	7	1.5
3	Adama-Asela road maintenance	Adama - Melkasa	20	1.5
4	Addis-Modjo-Meki road maintenance	Modjo-Meki	59	1.5
5	Adama - Methara road maintenance	Welenchit - Methara	70	1.5

The conditional survey was used for visual inspection to determine/survey the extent and type of distress, etc. The major distresses regarding maintained pavement road in five segments are shown in Table 4-4 below. The visual condition survey was used to measure various types and degrees or severity of distresses. The components which can be measured using visual condition survey were: surface defects (such as longitudinal joint cracks, potholes, raveling, bleeding and lacy edge); permanent deformation or distortion; fatigue cracking and patch deterioration. Most of the observed segment roads distress is medium to

high severity, according to Pavement Distress Identification Manual for Districts measurement in five road segments. So, most of the results indicated average severity of maintained road pavement districts. Based on road pavement manual, condition survey and interview of people who reside there. Probable failure causes of repaired roads were: heavy load, inadequate drainage, poor construction method and poor construction materials. The results shown under gray colors in Table 4-4 are high number of distress of maintained pavement roads.

Table 4-4: Maintained asphalt pavement distress in five road segments

S.No.	Observed maintained road distress		Road segments					Possible causes
			Semwo-Debreberhan	*Comando-Fitche*	*Adama-Melkasa*	*Modjo-Meki*	*Weienchit - Methara*	
1	Surface deformation	Corrugations	6	10	20	30	25	Faulty maintenance
		Rutting	80m	40m	30m	25m	100m	Heavy loads and poor construction methods.
		Shoving	12	10	23	17	25	Climate/durability
		Shallow depressions	5	10	16	30	18	Heavy Load/drainage
2	Cracking	Fatigue cracking	30	20	35	30	15	Repeated traffic loading
		Transverse Cracking	10	16	30	25	40	construction fault
		Longitudinal Cracking	15	14	25	25	35	Drainage/shoulder settlement
		Lacy Edge	28	36	43	54	60	Load/shoulder

								support
3	Disintegration	Potholes	25	35	53	59	38	Drainage/severe alligator cracking.
		Patches	10	17	25	30	19	Load
4	Surface defects	Raveling	Many	Many	Many	Many	Many	Material/climate
5	Drainage condition		2	2	6	3	5	Construction method/durability
6	Damaged Road safety (signs and furniture)		15	20	17	19	15	Durability/accident

Source: Field survey data on December 15-20, 2017

4.3.1 SEMBO-DEBREBREHAN ROAD SEGMENT

The Sembo-Debrebrehan road segment (40km) is part of the network of the Debreberhan-Ataye Federal road. This road segment is maintained throughout the year and the site survey results explain that the main maintained road is in poor condition.

Picture 4-1 below shows the visual observed data the subject road segment with 1.5 km length. In every maintenance situation, safety and accessibility are important considerations for everyone involved including the drivers who use the roads. The impact of these operations on highway maintenance process must accommodate the ever-present effect of traffic.

From observation, the state of the of maintained paved road in Sembo-Debrebrehan maintenance road segment is poor. However, some segments of the road have no problem, that is, close to Debrebrehan town, the maintained road is fairly good although the system is poorly maintained. The conditional survey photo was taken close to Debrebrehan at Koremaragefya as locally called. The particular distresses in each observed section using the visual survey data pictures are illustrated in Photo 4-1.

Major distress type of maintained pavement was: lacy edge, potholes, raveling, fatigue cracking and shoving and the probable causes for this distress were presented in Table 4-4 above.

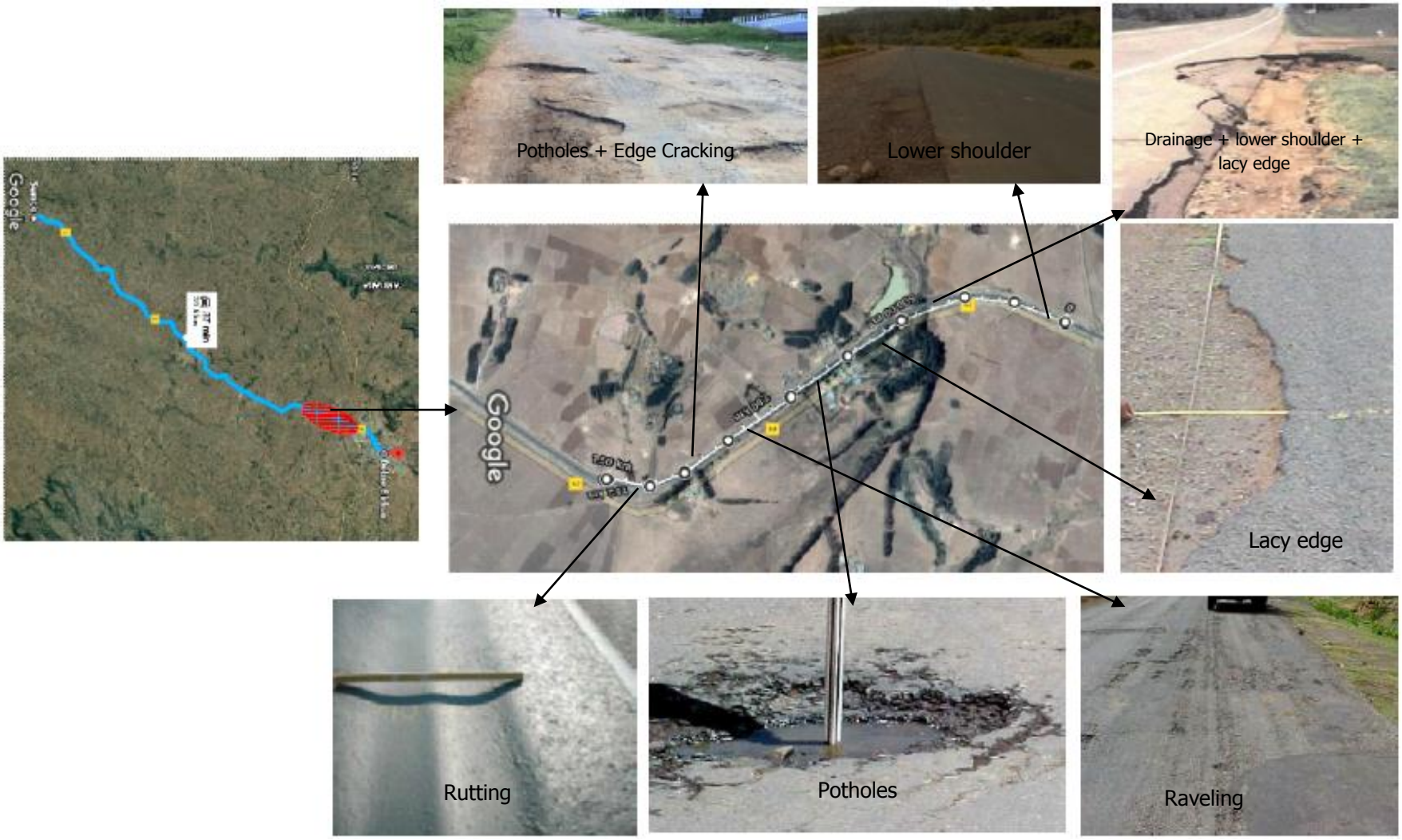


Figure 4- 3: Visual observed data from Debreberhan-Ataye road segment

4.3.2 COMANDO-FITCHE ROAD SEGMENT

The Comando – Fitche road segment is maintained frequently throughout the year with routine maintenance; however, it has deteriorated or failed before the liability period. Picture 4-2 below presents the detected area with 1.5 km length.

The Comando – Fitche road has exhibited maintained pavement deterioration and failures occurred shortly after their last rehabilitation. The visual field inspection was carried out on the existing pavement of failed sections. Most of the culverts provided on the road segment are concrete. The culvert is not adequate for a road with magnitude of flash floods crossing. Box culverts provided were few but functioned very well. There were no blocked box culverts observed while carrying out the survey. Culverts were blocked by both soil and bushes which were observed at the entrance of culvert. The most maintained pavement distress occurred here were: potholes, drainage, surface delamination, lacy edge, raveling and safety signs and furniture.

4.3.3 ADAMA -MELKASA ROAD SEGMENT

The Adama – Melkassa road segment is located in the southern direction of the Adama town. This road segment faced failures of maintained pavement. The maintenance was done regularly but the road pavement got distressed regularly too. Picture 4-3 below presents the photographic images/google map of the road segment with 1.5 km length.

The condition of the maintained paved road in the case of the Adama - Melkasa road segment in poor condition. The specific distresses in each observed section are illustrated in Picture 4-3. The most significant pavement defects were: potholes, cracks, edge defects, depressions and corrugation. In addition; overloading, pavement age, weather, drainage, construction quality as well as construction materials, maintenance policy are probable causes of the road pavement deterioration.

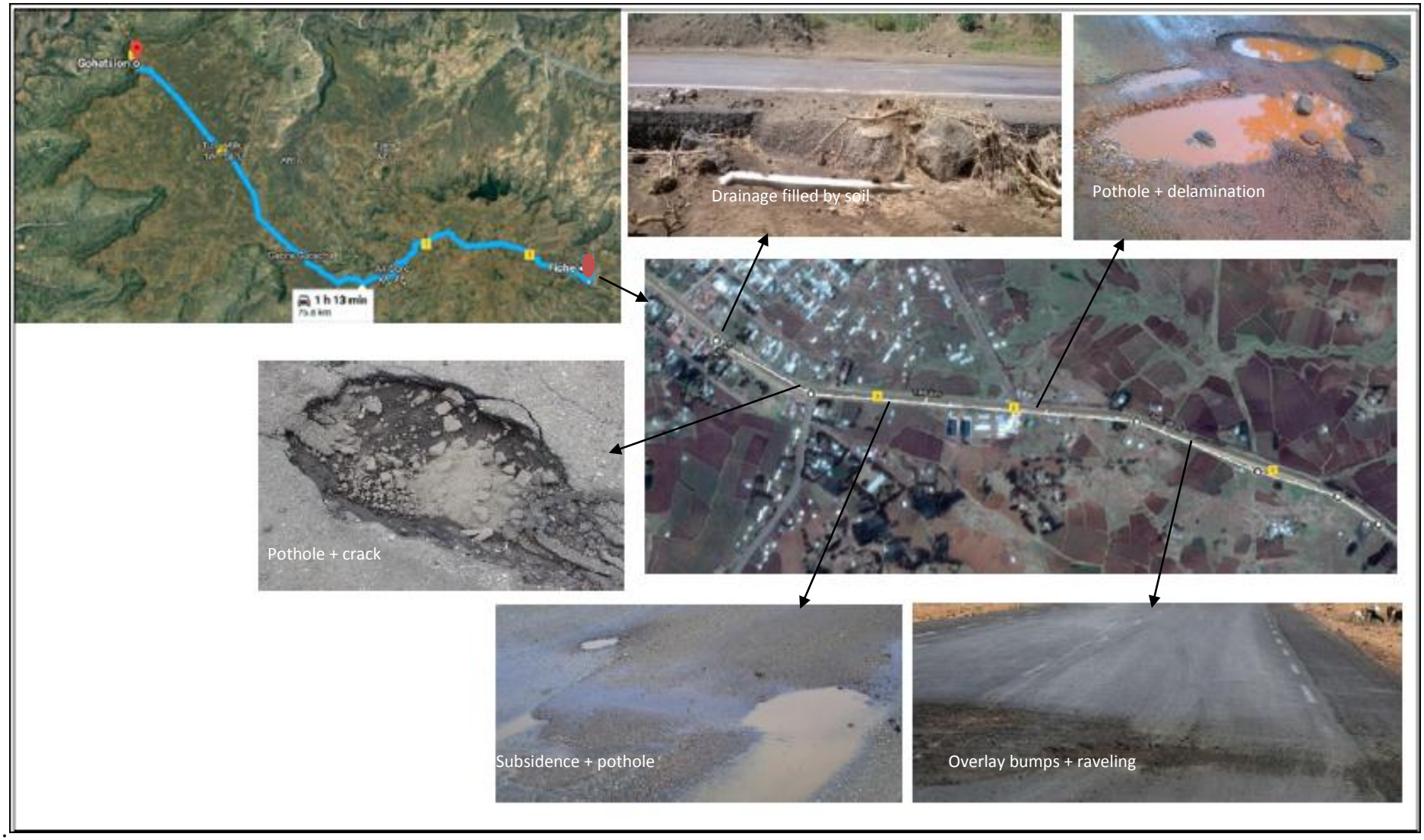


Figure 4- 4: Physical data on Comando - Fitche road segment

Figure 4- 5: Physical data on Adama - Melkasa road segment

4.3.4 MODJO - MEKI ROAD SEGMENT

The Modjo - Meki road is located in the southwestern direction of Modjo. This road segment frequently fails although maintained regularly. Picture 4-4 below presents the photographic image/google map of the road segment within 1.5 km length. The most significant defects observed in the field were: potholes, rutting, cracks, edge defects, drainage and overlay bumps and the possible causes for the distress were: overloading, weather, drainage, construction quality as well as construction materials, maintenance policy and soil condition. For example; during the field survey, parts of the road that were washed away during the rains were observed and photographs taken. The part of the road was washed away as a result of inadequate drainage facilities to allow water to cross the road without interruptions and the ditches were filled with eroded sand stones and other materials.

4.3.5 Welenchit – Methara Road Segment

The Welenchit – Methara road segment is located east of Adama towards Awash. This road segment frequently fails although maintained regularly. Picture 4-5 below presents the photographic image of the road segment within 1.5 km length.

The major common distresses observed on the road segment were: rutting, shoving, cracking, lacy edge, potholes and drainage and the distresses are presented in Table 4-4 and illustrated in Picture 4-5. The possible causes for the distress were: overloading, weather, drainage, construction quality as well as construction materials and maintenance method. For example; during the field survey, it was observed that a portion of the road was washed away during the rains and a photograph was taken. The part of the road that was washed away was because of inadequate drainage facilities to allow water to cross the road without interruptions and ditches were filled with eroded sand, stones and other materials. The main cause of the deterioration was due to vertical deformation in the wheel tracks by every vehicle that passes over some induced transient strains in the pavement layers and the sub grade. Throughout the life of the pavement, these minute pavement strains accumulate and appear as deformation and eventually, cracking of the road surfacing.

In view of the above road segments, it is concluded that in every maintenance situation, safety and accessibility are the most important considerations for everyone involved, including the drivers who use the roads. The influence of these actions on road maintenance process must be well recognized and thorough solutions should be sought about.

Figure 4- 6: Physical data on Modjo - Meki road segment

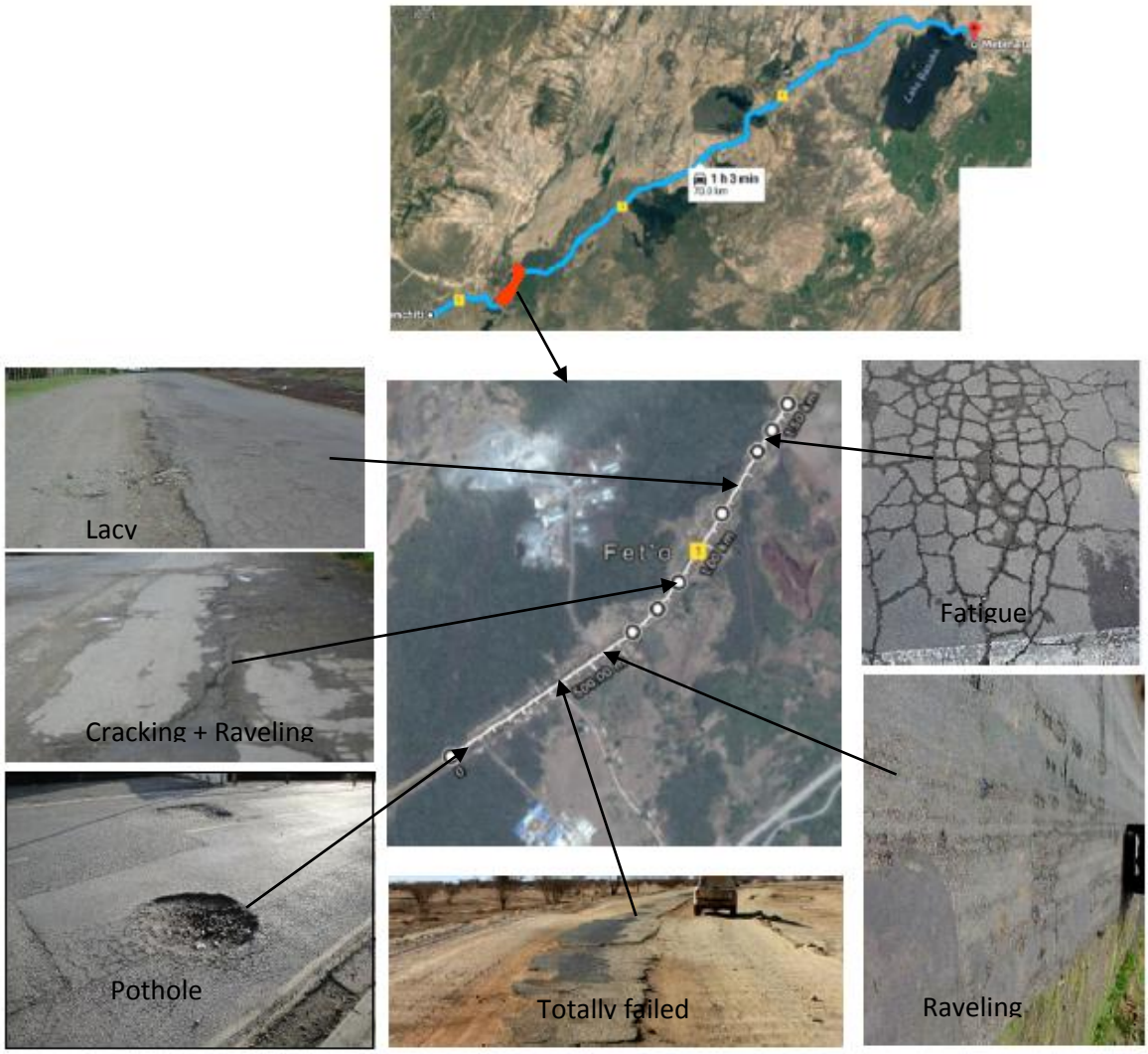


Figure 4- 7: Physical data on Welenchit – Methara road segment

4.4 RESULTS FROM QUESTIONNAIRES SURVEY

Questionnaires were distributed to selected individuals in ERA, Contractors and Consultants that are engaged in maintenance activities of the Federal paved roads. Another questionnaire was distributed to vehicle operators or road users who used the maintained roads. The questionnaire encompassed of closed and open-ended questions on issues that are related to the study.

Table 4-5: Response rates

	No. of distributed questionnaires	No. of returned (The response)	The response rate
Professional from Client/ERA	12	10	83.33
Professional from Contractors'	20	16	80.00
Professional from Consultants'	13	10	76.92
Maintained Road users'	48	40	83.33
Total	93	76	81.72

Source: Field survey data on October 20, 2017

A response rate of 50% is adequate for data analysis and reporting; 60% is good and above 70% is very good (Mugenda, 1999). In the study case, the average response rate was calculated at 81.72% and therefore the results of the analysis of the data were very good.

4.4.1 GENERAL BACKGROUND OF THE RESPONDENTS

4.4.1.1 General Background of the respondents from ERA, Contractors and Consultants

The questionnaire survey included four questions to observe the respondents' background and to ensure the quality and the experiences of the participants. Table 4-6 below presents the summary in respect of the background of the respondents.

Table 4-6: Summary the result on the background of respondents

General Background	Frequency	Percentage
Organization		
Ethiopian Roads Authority	9	25.0
Contractors	14	38.9
Consultants	9	25.0
Others	4	11.1
Level of Academic Status		
Second degree	17	47.2
First degree	11	30.6
Diploma	5	13.9
Others	3	8.3
Current Position		
Top level management	9	25.0
Mid-level management	16	44.5
Bottom level management	8	22.2
Others	3	8.3
Experience in the road sector		
0 – 5 years	10	27.8
5 - 10 years	17	47.2
10 – 15 years	6	16.7
15 – 20 years	3	8.3
Grand Total	**36**	**100.0**

Source: Field survey data on October 20, 2017

(i) Respondents' working Organization

The majority of the participants (89.9%) were professionals from the ERA, contractors and consultants. Other participants accounted for only 11.1% and are not currently part of the ERA but had worked and left the organization five years ago.

(ii) Respondents' Level of Academic Achievement

Most of the participants (77.8%) have at least Bachelor's Degree indicating that the respondents are highly qualified and with disciplines in civil engineering and Construction Technology and Management.

(iii) Respondents' Current Position and experience in the road sector

In was illustrated in Table 4-6 that more than half of the respondents (69.4%) were positioned on top and medium level of management with the majority of the respondents (72.2%) having more than five years of experience in the road maintenance work. Only 27.8% of respondents have less than five years' experience.

In view of the foregoing, it can be concluded that the results of the analysis of Part I of the questionnaire indicated that the majority of the participants were at senior levels of management with sufficient education acquiring working experience and knowledge in the paved road maintenance project of the Ethiopian Roads Authority. Thus, the findings assured the quality of the respondents and validated the survey with open-ended questions.

4.4.1.2 General Background of the respondents from End Users

Part one of the questionnaire was meant to obtain general information about the involvement of the respondents. It consists of information related to their satisfaction of maintained paved roads, the condition of the roads and factors affecting frequent failures of maintained paved roads. As shown in figure 4-3 below, 60% (24 out of 40) are male and 40% are female respondents road users.

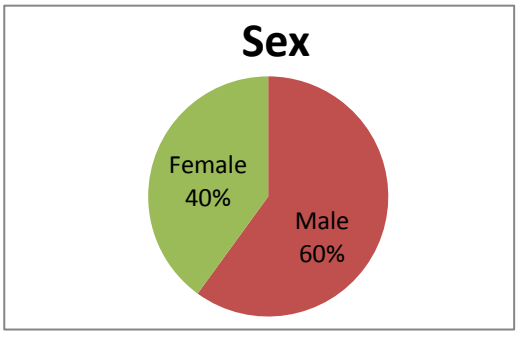


Figure 4-7: The Gender classification of respondent

Figure 4-4 below shows that the majority of the respondents have achieved at least above Diploma (87%). This indicates that the participants have know-how on maintained road condition and they can identify the causes that affect the frequent failure of the road.

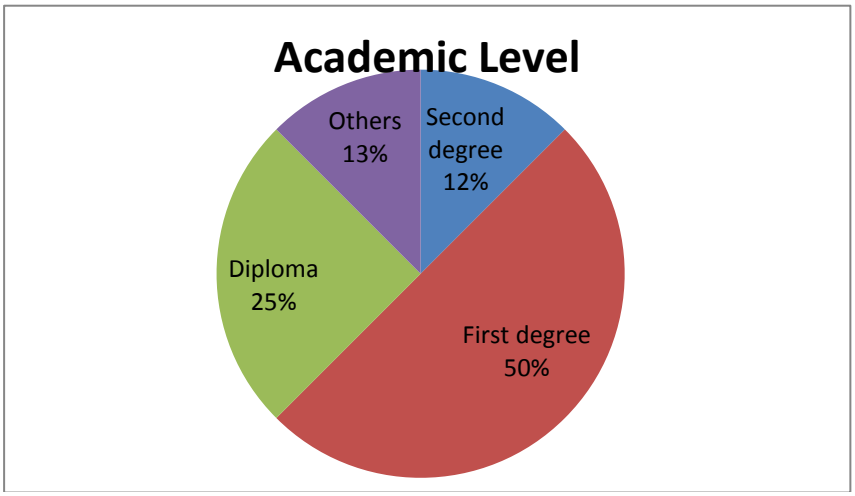


Figure 4-8: The academic level of respondents' summary.

Most of the participants (72%) are working in government offices as illustrated in Figure 4-5. The respondents are not only passengers but most of them reside at the study area. Therefore, the respondents know the condition of the case study area.

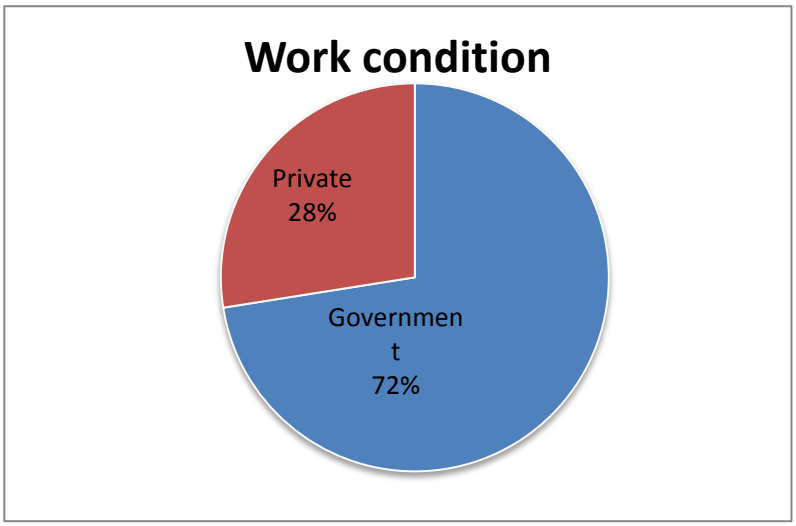


Figure 4-9: The working condition of respondents' summary

At conclusions, it can be substantiated that road user respondents had understanding and awareness of the maintained road condition. Therefore, the results confirm the reliability of the respondents regarding the main part of the questionnaire survey.

4.4.2 CLIENT/ERA PERCEPTION

4.4.2.1 The general factors that mostly affect the maintained paved Federal Roads

Frequencies for top and minimum ranked severity of factors which explained the general causes for frequent failures of maintained paved roads were provided by the respondents and are depicted in Table 4-7 below. The major factors that cause failures are: workers' skill, maintenance culture, quality materials and soil condition whereas the least ranked was the 'highway amenities'. The average indices of the highest and the lowest ranked factors were calculated at 4.60 and 1.30. respectively.

Table 4-7: General factors that mostly affect maintained asphalt pavement Federal roads

No.	General Causes	Average Index	Rank
1	Quality of work	4.10	6
2	Required cost	3.10	14
3	Required period	4.10	6
4	Quality of design	3.10	14
5	Working load	3.50	13
6	Workers' skill	4.60	1
7	Data inventory and data base	3.60	11
8	Heavy Traffic	3.00	16
9	Maintenance Culture	4.60	1
10	Highway Amenities	1.30	17
11	Laboratory and Insitu Tests on Soil	3.80	9
12	Quality Materials	4.60	1
13	Supervision	4.10	6
14	Knowledge Base	3.70	10

15	Weather Condition	3.60	11
16	Drainage supply	4.50	5
17	Soil Condition	4.60	1
18	Others	1.00	18

Source: Field survey on October 20, data 2017

Table 4-7 above illustrates that most of the factors are in normal and major cause category except that two factors were not causes at all (highway amenities and others). The 'cause' factors which are indicated on the Table 4-7 are 'Quality of Work', 'Required Period', 'Data inventory and data base', 'Laboratory and Insitu Tests on Soil', 'Supervision', 'Knowledge Base', 'Weather Condition, and 'Drainage supply'. While the factors which are 'Highway Amenities' and 'Others' in "Not Cause" category.

Table 4-7 shows that 'workers' skill', 'maintenance culture', 'quality materials' and 'soil condition' are major causes of frequent deterioration. When there are more grievances on road maintenance, it shows that the maintained roads were in poor condition. So, the client should take these factors as the major causes of failures of maintained paved Federal roads.

4.4.2.2 Factors affecting Maintained Road Project Completion within Scheduled Time

Table 4-8 below shows the factors that affect road project failures of maintained paved Federal Roads for completion within scheduled time.

Table 4-8: The factors that affect the maintenance road projects' failure

Causes	No. of respondent	Rank
Uneven increase/fluctuation of material price	7	1
Shortage of material, manpower	6	2
Lack of efficient/competent contractor	5	3
Extreme site condition like rain, flood etc.	7	4
Modification of plan or design related issues	4	5
Dependency on donor funding	4	6

Knowledge and planning	4	7
Inadequate management capacity	2	8
Poor supervision by client (ERA)	6	9
Lack of expert technical personnel by client (ERA)	5	10
Slow administrative process by ERA	4	11
Extra work requirements of contractors	3	12
Contract disputes or issues between the parties	3	13
Political influence	5	14
Delay on payment of contractor	8	15
Inadequate government support	4	16

Source: Field survey data 2017/18

Therefore, the following are the major challenges, in respect of priority, which delay maintenance of the Federal paved roads, according to the respondents.

1. Uneven increase/fluctuation of material prices;
2. Shortage of materials, manpower;
3. Lack of efficient/competent contractors;
4. Extreme site condition like: rain, flood etc.;
5. Modification of plan or design related issues;
6. Dependency on donor funding;
7. Knowledge and planning;
8. Inadequate management capacity;
9. Poor supervision by client (ERA); and
10. Lack of expert technical personnel by client (ERA).

Table 4-8 shows that price fluctuation of construction materials is the major challenge on timely completion of road maintenance projects. If the maintenance takes longer, road

deterioration could be high. Allocation of funds affects the start of the project and also delays the payment of the contractor. If the ERA fails to pay the contractors on time, they would be unable to carry out the activities timely due to shortage of fund. Poor supervision and lack of technical personnel in client (ERA) is also a cause for failure. Therefore, failures on time completion of paved roads under maintenance would affect the satisfaction of road users costing them efficient travel time, accidents, vehicle operation, etc. So, the factors such as 'Lack of efficient/competent contractor' and 'Knowledge and proper planning' mostly affect the timely completion of paved road maintenance. Most of the causes depicted in Table 4-8 are related to each other. Therefore, these causes entail proper attention by the ERA to safeguard the effective management of maintained paved roads which are significant to end users.

4.4.2.3 Quality Related Factors

This questionnaire survey has five questions on the quality of work attained in road maintenance by using a five point of Likert scale and the results are presented in Table 4-9.

Table 4-9: The percentage of responses on quality of work

No.	Quality-related factors	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	The levels of quality achieved on the maintained paved road are sufficient.	0	60	20	20	0
2	Material quality controls on the maintenance projects are sufficient.	20	40	30	10	0
3	The amount of resource allocated for implementing quality objectives are enough.	20	40	40	0	0
4	The current maintenance road contracting type will improve the service quality during the extended period.	0	50	10	40	0
5	The level of training (pre-and-on the job) for staffs are enough.	30	50	20	0	0

Source: Field survey 2017/18

The majority of the respondents (60%) considered the levels of quality achieved on the maintained paved road as insufficient. Only small number of participants (20%) said that the level of quality is sufficient whereas another group of participants were neutral. Table 4-9 explained that 20% of the respondents strongly disagreed and 40% disagreed on the sufficiency of quality control while 30% stood neutral. The remaining 10% stated that the material quality control on the maintenance road projects is sufficient. Sixty percent (60%) of the respondents at least disagreed on the amount of resources allocated for implementing quality maintenance of paved road were enough; whereas, the remaining 40% neither disagreed nor agreed on the statement.

Half of the respondents (50%) stated that the current road maintenance contracting procedure will not improve the service quality during the extended period while the small group of participants marked that the statement is neutral. Table 4-9 illustrates that the majority of the respondents (80%) disagreed on the statement of the level of training (pre-and-on the job) for staffs is enough. Other respondents (20%) respond to be average. Therefore, quality of work on road maintenance can be concluded that the levels of quality achieved in respect of: material quality controls; amount of resources allocated, and level of training for staffs were insufficient.

4.4.2.4 Risk sharing related factors

In this case, the participants presented their opinions in respect of three statements under five scale indicators and the results are presented in Table 4-10 below.

Table 4-10: The percentage of responds on risk sharing between the client and contractors

No	Statements	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Contractors do not need to take any responsibility for poor quality of works	0	30	10	60	10
2	Road maintenance construction project risks should be properly identified and shared between the contractor and the client	20	40	40	0	0
3	Risk sharing would bring a sense of discipline and	0	0	20	70	10

	responsibility to the contractor on road contracts					

Source: Field survey 2017/18

According to Table 4-10, the majority of the respondents (60%) agreed with the fact that contractors should not take any responsibility for poor quality of works while 30% responded otherwise and the remaining 10% stood neutral. In Table 4-10 above, it was stated that the majority of the respondents (60%) at least disagreed on the statement of road maintenance construction project risks to be properly identified and shared between the contractor and the client while the remaining responded neutral.

Most of the respondents (80%) agreed that risk sharing would bring a sense of discipline and responsibility to the contractor while 20% neither agreed nor disagreed. Therefore, it can be concluded that contractors need to take responsibility for poor quality of works during road maintenance activities especially when the roads deteriorate quickly. As ERA takes the responsibility of identifying the risks properly and share the identified risks with the contractors which enhances the maintained road to be conducive and durable to the end users as well as to the Country. Thus, all the stakeholders would bring a sense of discipline and responsibility by sharing risks. So, taking responsibility of risks that can happen pre or post maintenance works can reduce the factors which affect the frequent failures of maintained roads.

4.4.2.5 Improvement of the effectiveness of maintenance work and efficiency of staff

Quality and performance of ERA staff play a significant role in properly implementing road maintenance projects. The staffs' responsibilities increase from simple initial planning to execution of road maintenance works. Accordingly, the ERA should provide the required training to the staff to improve their efficiency. The statement in this sub-section explores the importance of effective road maintenance work based on the staff efficiency. Table 4-11 below presents the responses regarding improvement of the effectiveness of maintenance works and staff efficiency.

Table 4-11: The improvement the effectiveness of maintenance work and efficiency of staff

No.	Statements	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Setting the performance measures of the completed works would help the contractors to do quality works	0	0	10	70	20
2	The current level of efficiency regarding road maintenance by ERA staff needs improvement	0	0	10	60	30
3	The current status of maintained paved Federal road need improvement regarding road maintenance project by ERA	0	0	0	40	60

Source: Field survey 2017/18

Most of the respondents (90%) agreed in the statement of setting performance measures that completed works would help the contractors to do quality works. Only small groups (10%) stood neutral.

Table 4-11 states that the majority of participants (90%) agreed that the current level of efficiency regarding road maintenance by ERA staff needs improvement. Only a small group of participants neither agreed nor disagreed on the matter. On the other hand, all the participants strongly agreed on the current status of maintained paved Federal road need improvement regarding road maintenance project by ERA. Therefore, setting the performance measures of the completed works; improving the current level of efficiency regarding road maintenance by ERA staff and improving the maintenance culture is needed for maintained paved Federal road as respondents replied.

4.4.2.6 Increasing Transparency in Maintenance road project execution

Table 4-12: The percentage of responses regarding increase in transparency

No.	Statements	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed

		%	%	%	%	%
1	The current contracting method can lower the level of possible corruption/mismanagement in the contracting process.	0	0	50	40	10
2	The nature of current contracting method mainly focuses on user satisfaction	0	50	40	10	0

Source: Field survey data 2017/18

Table 4-12 above illustrates that half of the respondents agreed on the current contracting method to lower the level of possible corruption/mismanagement in the contracting process while half of them stood neutral. On the other hand, half of the respondents disagreed on the nature of current contracting method which mainly focuses on user satisfaction. Therefore, there is still doubt (half) on use of the current contracting method to lower possible corruption/mismanagement and to increase user satisfaction. Due to this, the maintenance work has quality and sustainability problems.

4.4.2.7 Technical feasibility barriers in road maintenance

The questionnaire survey was meant to find out the technical capability of the ERA in executing a better-quality maintenance of roads. Table 4-13 below states the percentages of responses on the technical feasibility barriers in road maintenance.

Table 4-13: The technical feasibility and Barriers in maintenance roads

No.	Statement	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Contractors' capacity and commitment would be a problematic issue in road maintenance.	0	0	20	70	10
2	Construction industry in Ethiopia is still underdeveloped to implement effective road maintenance contracts	0	0	20	70	10
3	Lack of government's budgetary allocation for the long-term commitment could be a problem	0	0	30	50	20

Source: Field survey data 2017/18

The majority of the respondents (80%) agreed that the contractors' capacity and commitment would be a problematic issue of concern in road maintenance while the remaining respondents were neutral. In addition, most of the respondents (80%) stated that construction the industry in Ethiopia is still underdeveloped to implement effective road maintenance contracts. Table 4-13 above presented that 70% of the respondents agreed on lack of government's budgetary allocation for the long-term commitment to be a problem. and the remaining respondents neither agreed nor disagreed on this statement. Therefore, it can be concluded that regarding contractors' capacity and commitment; the effective implementation of road maintenance contracts and lack of budgetary allocation are barriers to implement the maintenance of road.

4.4.2.8 Maintained paved Federal road condition evaluation

In this regard, the percentage of responds on maintenance culture and maintained road surface condition that resulted from the survey data analysis is presented in Table 4-14 below.

Table 4-14: Percentage of responses regarding maintained road condition evaluation

No.	Statements	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Maintained paved Federal Road condition status is good.	**50**	10	20	20	0
2	Present pavement evaluation method used by ERA is adequate for evaluating the pavement for structural, functional and safety of maintained road condition.	0	**60**	30	10	0
3	ERA apply different types of maintenance treatment selection techniques that are mandatory for recommending specific and cost effective remedial.	0	**80**	20	0	0
4	There is well-established Road maintenance	0	**40**	30	30	0

	management system in ERA for effective planning and management of pavement network.					

Source: Field survey data 2017/18

Table 4-14 presents that about 60% of the respondents strongly disagreed that the maintained paved Federal Road condition status was good while a small number of respondents (20%) agreed on the condition. The remaining 20% of the respondents neither agreed nor disagreed on the statement. Among the respondents, 60% of them disagreed that present pavement evaluation method used by ERA is adequate for evaluating the pavement for structural, functional and safety of maintained road condition. Thirty (30%) of the respondents stood neutral to the statement. Only a small number of respondents (10%) agreed on the adequacy of evaluating the pavement for structural, functional and safety of maintained road condition by ERA.

Table 4-14 further shows that the majority of the respondents (80%) disagreed that the ERA applies different types of maintenance treatment selection techniques that are mandatory for recommending specific and cost effective remedial measures while the remaining respondents (20%) stood neutral. In addition, Table 4-14 illustrates that forty percent (40%) of the respondents disagreed on the well-established road maintenance management system within ERA for effective planning and management of pavement network while 30% of the respondents agreed to the statement.

Therefore, current condition of maintained paved federal roads; evaluation method of the pavement for structural, functional and safety of maintained road condition and maintenance treatment selection techniques are not rationally established. Similarly, there is doubt on the effectiveness of the road maintenance management system. Hence, the above are the likely factors that cause the frequent failure of maintained paved Federal roads.

4.4.2.9 Implementation of effective road maintenance works in ERA

The effective implementation of maintenance enhances the sustainability of maintained roads. The questionnaire survey in this regard was investigated to assess the importance of effective implementation of road maintenance works based on five-point Likert scale as described below.

(i) Main problems for practicing different road maintenance pavement evaluation methods in ERA

Figure 4-6 below shows the respondents' opinions on ranking the main problems in practicing different road maintenance pavement evaluation methods in ERA.

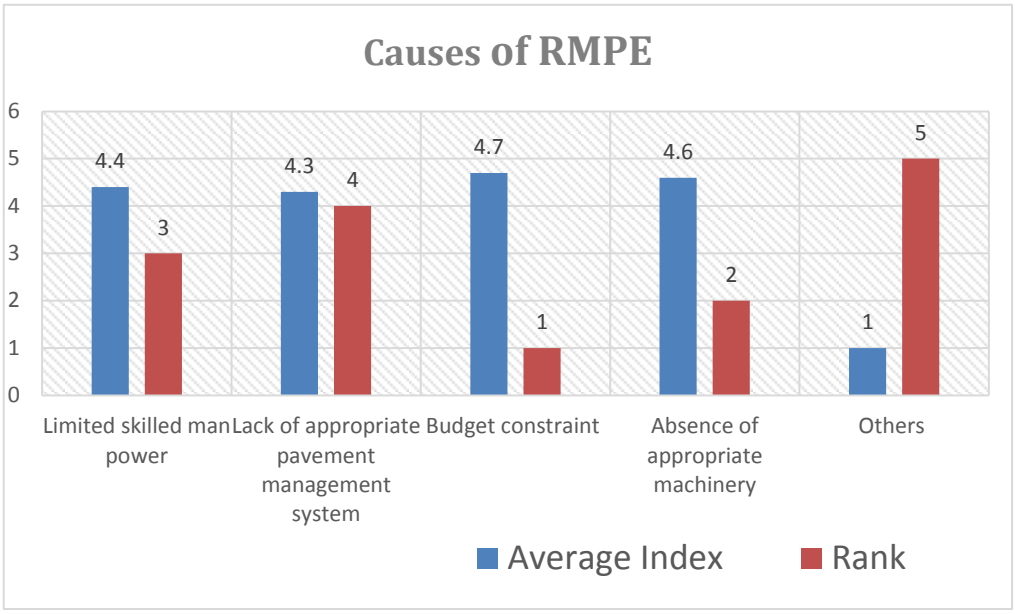


Figure 4-10: Causes of practicing road maintenance pavement evaluation (RMPE

The respondents ranked the factors as follows:

a) Budget constraint;
b) Absence of appropriate machinery;
c) Limited skilled man power; and
d) Lack of appropriate pavement management system.

Thus, the major challenges for practicing different RMPE are budget constraint and absence of appropriate machinery. Further, shortage of skilled manpower is also a challenge for practicing the RMPE. Hence, these problems are the causes for frequent failures of maintained Federal roads.

(ii) Main constraints for implementation of effective road maintenance works in ERA

Figure 4-7 below illustrates rankings of the main causes of failures of maintained paved roads based on five-point indicators of Likert scale.

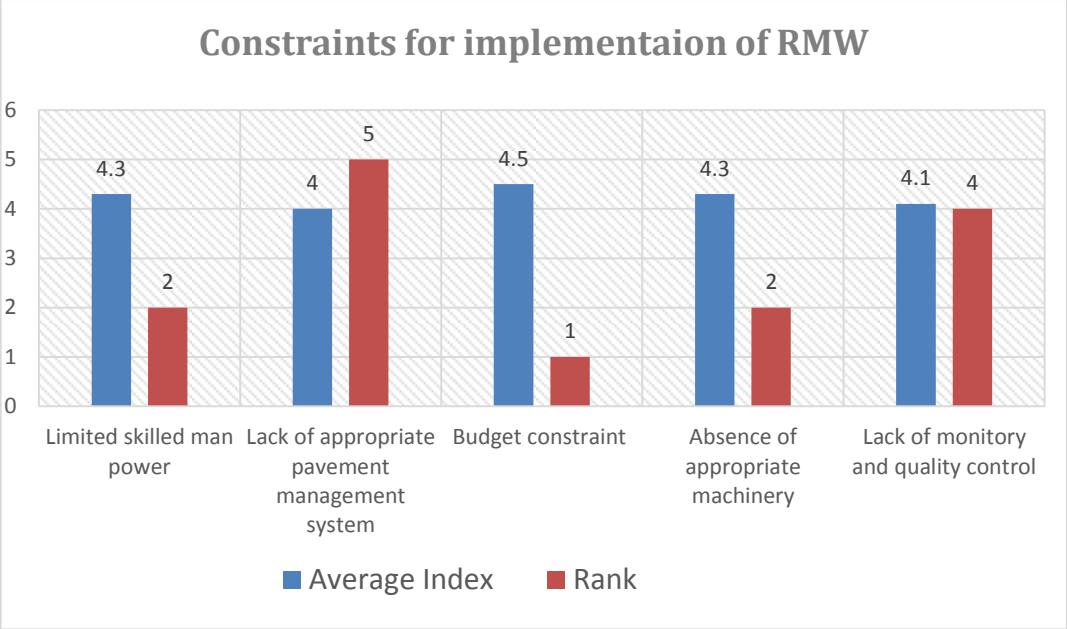


Figure 4-11: The summary of the constraints of effective Road Maintenance Works

Occurrences of the best and the least ranked factors that designated the major causes of implementation of effective road maintenance works are vital to be considered. The major constraints of effective road maintenance works in the ERA are: budget constraints; limited skilled manpower, absence of appropriate machinery and lastly lack of monitory and quality control were calculated at 4.5 ,4.3,4.3 and 4.1 of average index respectively.

Therefore, it can be concluded that budget constraint, Limited skilled man power and Absence of appropriate machinery are the major constraints for implementation of effective road maintenance works at the ERA. The above factors adversely affect only road maintenance activities but it also affects the durability, quality, national development and users' satisfaction in every manner.

(iii) The main causes that constraints to implement of Pavement road maintenance management

Frequencies for the top and least ranked causes which described the constraints to implement Pavement Road Maintenance Management System (PRMMS) in ERA from the listed causes were significant to be well-thought-out. Figure 4-8 below states the first important constraint to implement PRMMS in ERA is 'lack of awareness of the benefits and costs of the PRMMS'; the second is the 'absence of appropriate machinery'; the third is 'budget constraint' and the forth is 'limited skilled manpower' with average indices of: 4.9, 4.1, 4.0 and 3.2 respectively.

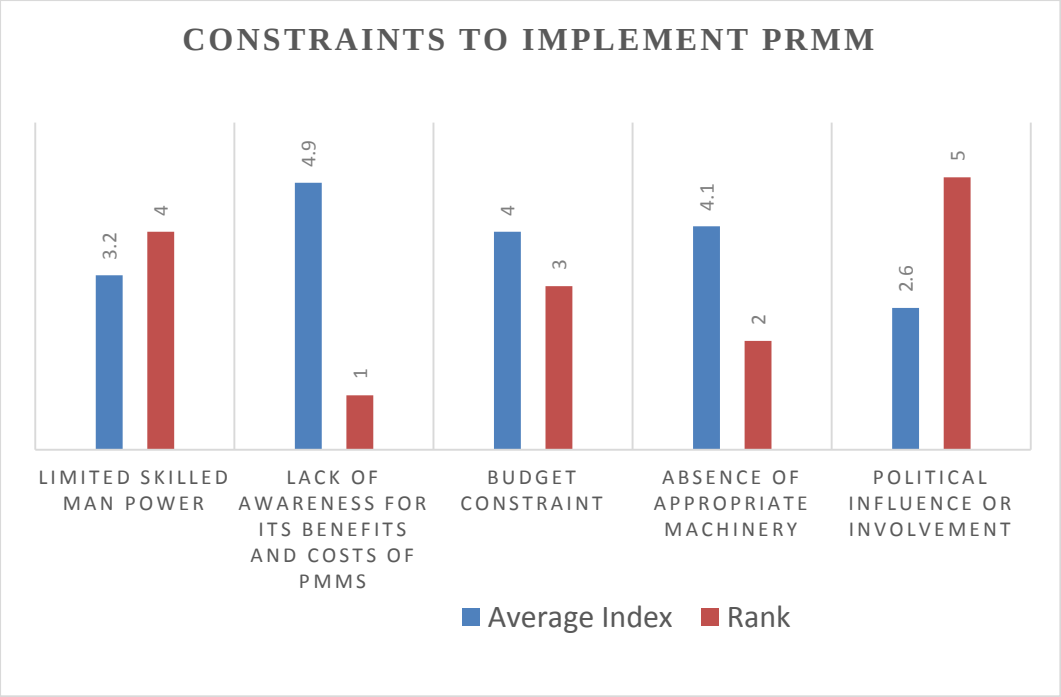


Figure 4-12: The constraints for Pavement Road Maintenance Management

Therefore, the above-mentioned constraints were identified as the causes for the failures of maintained paved Federal road. The PRMMS implementation problems are the root causes of maintenance roads.

4.4.2.10 Achievement of road maintenance projects within specified schedule and scope

The maintenance road project is considered unsuccessful if it fails to be completed within the scheduled time achieving the target. This questionnaire survey asked the participants three questions which create the understanding of the maintenance road success based on maintaining schedule. The results of the analysis of the respondents' responses are illustrated in Figure 4-9 below.

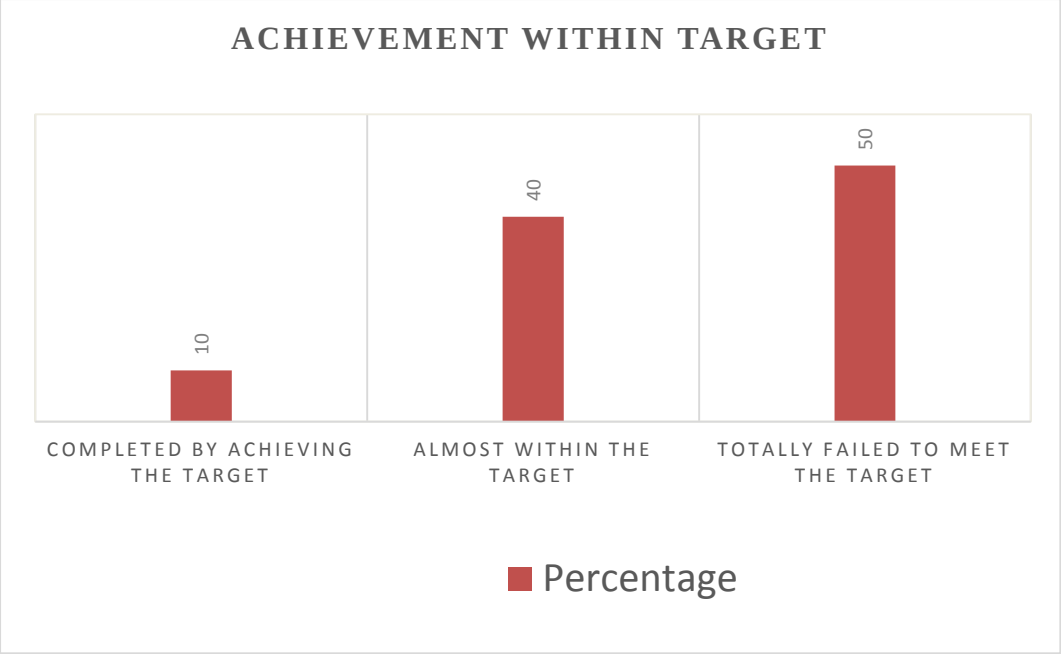


Figure 4-13: maintenance road projects' completion by achieving the target

Regarding the above, half of the respondents (50%) stated that road maintenance projects totally failed to achieve the target while 10% of the respondents believed otherwise. The remaining forty percent (40%) described that the road maintenance projects were completed almost within the target. Finally, the majority of the respondents believed that many completed road maintenance works failed to meet their targets.

4.4.2.11 Safety features design on maintained roads

The safety features of maintained roads were of concern and the convenience of road during the harsh time. Safety design on maintained roads focuses on the existence of bends, parapets/ guardrails & other safety features and the condition were rated by using five-point Likert scales and shown in Figure 4-10 below.

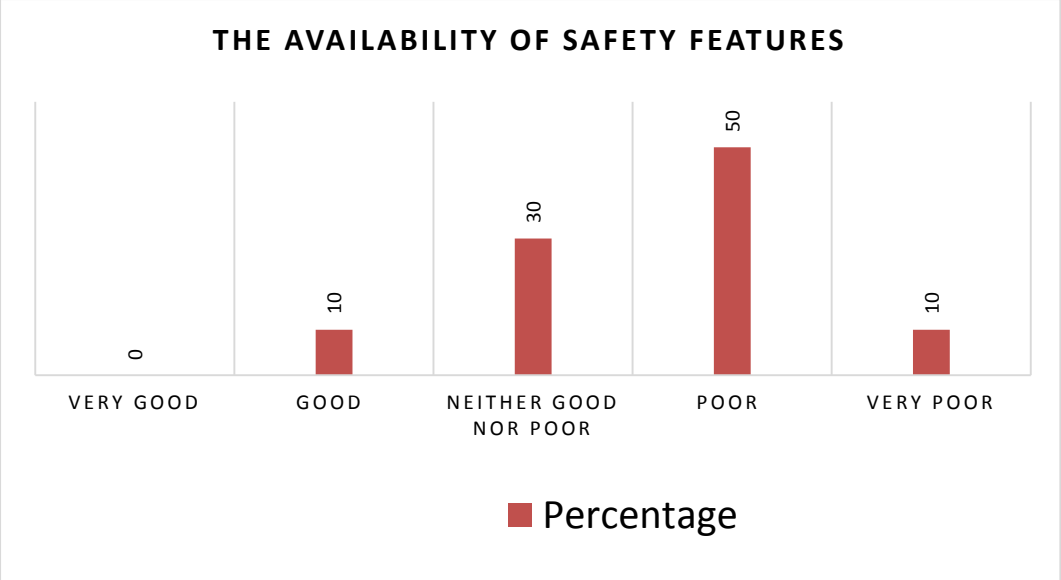


Figure 4-14: The existence and condition of safety features on maintained road

Based on Figure 4-10 above, only 10% of the participants think that the existence and condition of safety features in maintained federal roads is good while the majority of respondents (60%) stated as poor. Thirty percent (30%) of the respondents rated as neither good nor poor. Therefore, the existence and condition of safety features on maintained federal roads is insignificant. This questionnaire survey concludes that the absence of safety features on maintained road adversely affect the smooth service of maintained road surface and the users.

4.4.2.12 The actions that need considerations during road maintenance activities and appropriate drainage facilities in Ethiopia

Figure 4-11 presents the respondents consideration during the road maintenance projects. Topography, period of construction and cost of construction were the major points accounting for 26%, 23% and 20% respectively. In addition, the remaining criteria such as state of road and class of road are close to the above points for consideration. Figure 4-11 below presents the results of the analysis concerning the subject.

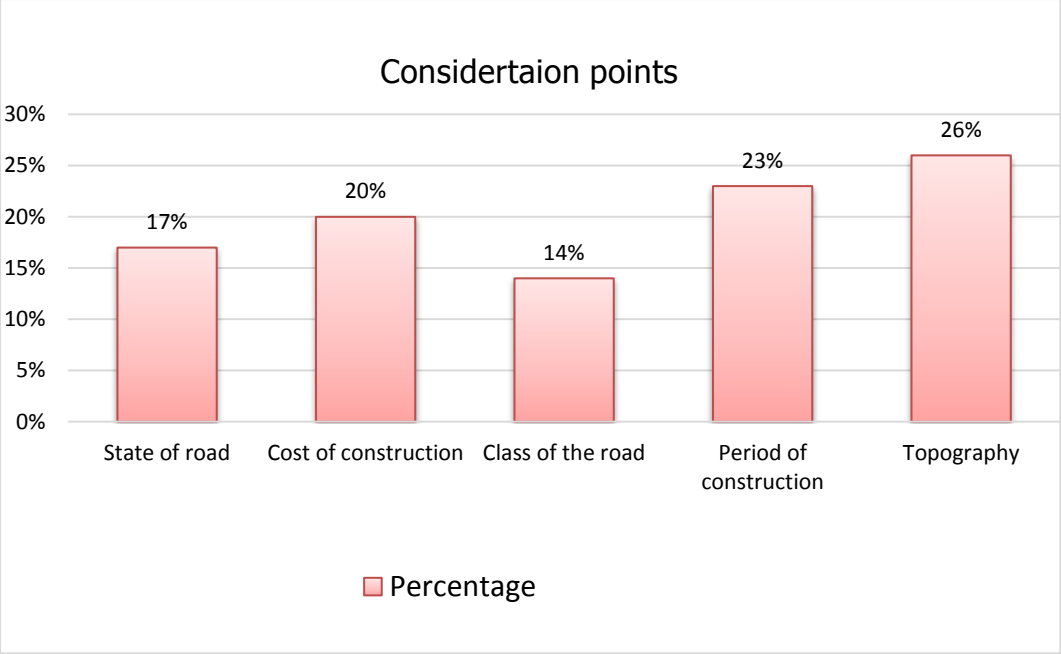


Figure 4-15: The considerations of safety aspects during road maintenance project

Therefore, it was important to know the critical factors considered when designing a road maintenance and facility. This is because the above-mentioned factors more or less adversely affect maintained roads and helps to understand the reasons behind the design road maintenance projects.

4.4.2.13 Performing inspection to ascertain the state of the maintained paved road in Ethiopia

The professionals from ERA had to check the poor state of maintained paved roads in respect of performance inspection. Figure 4-12 below illustrates the responses of the persons doing inspection on paved maintenance roads.

Based on the results in Figure 4-12, the majority of the respondents (60%) replied to the question that ERA has to perform inspection to ascertain the state of the maintained paved road monthly while 20% stated that ERA should do inspection every six months. The remaining 20% of the respondents stated every three months. Therefore, the road authority should carried out inspection of the maintenance roads and its drainage facilities on monthly basis but that emergency inspection be carried out when a problem occurred to ascertain its extent and to carry out required action.

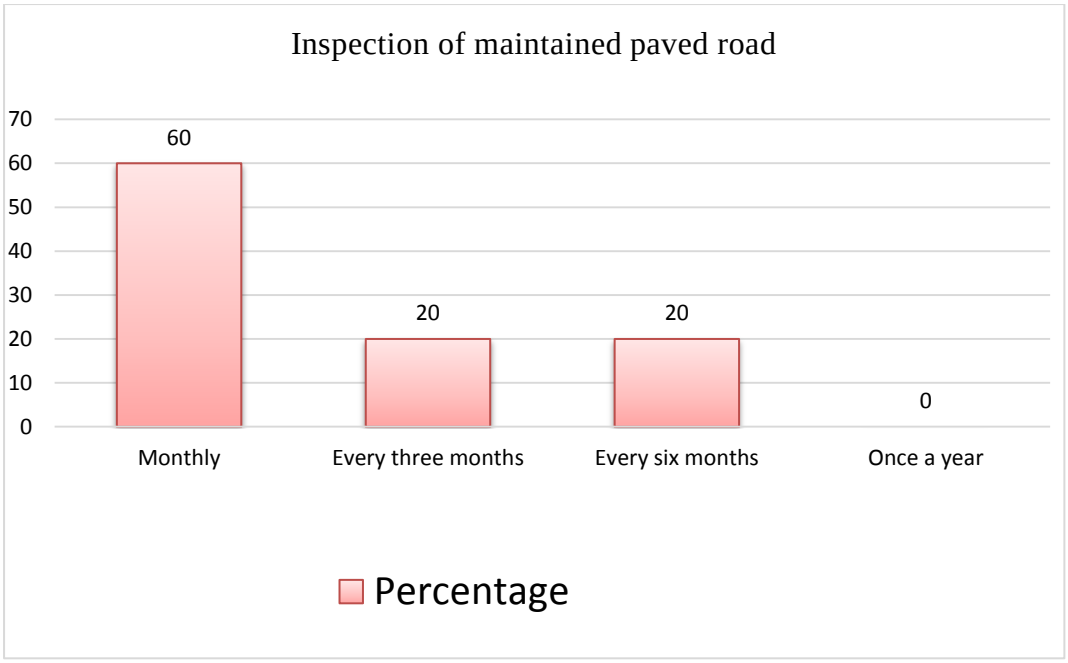


Figure 4-16: The considerations of inspection during road maintenance project

4.4.2.14 Remedy to deteriorated state of the drainage system on maintained paved Federal road

Figure 4-13 presents the percentage of responses of remedy to deteriorated state of the drainage system on maintained paved federal road.

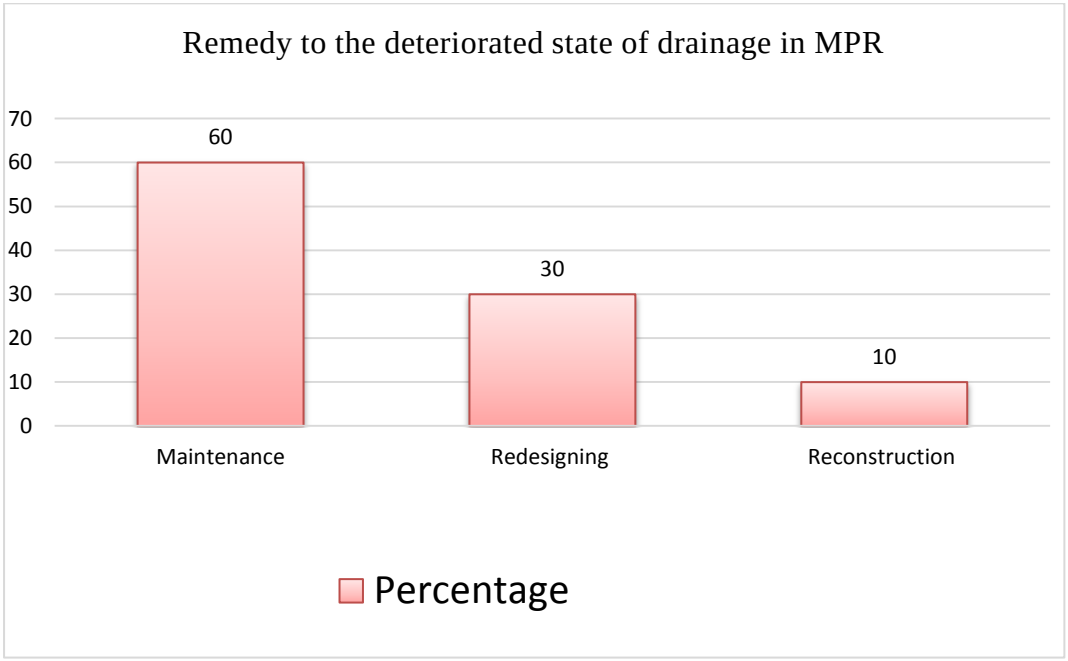


Figure 4-17: The remedy to the deteriorate state of the drainage system

Most of the respondents (60%) stated that the remedy for deteriorated drainage facility is maintenance, 30% of the respondents believed redesigning is the solution and the remaining respondents (10%) marked the reconstruction of the worsened drainage facility as a solution.

Therefore, deteriorated drainage increases the magnitude of the water flow on the surface of the maintained road. Thus, the designing of the road maintenance was not sufficient to satisfactorily ascertain the amount of water that would cross the road at a point in time and therefore the design lacked capacity to adequately drain the runoffs during the rains. However, poor workmanship by the contractor during construction and poor maintenance culture also contributed to the drainage problems which causes frequent failure of maintained paved Federal roads in Ethiopia.

4.4.3 CONTRACTORS PERCEPTION

In this section, the main aim is to analyze and discuss the results based on the responded questionnaire from the contractors who work on Federal road maintenance activities. Accordingly, it needs to identify the causes of frequent failures of maintained paved Federal road networks.

4.4.3.1 The general factors that mostly cause the failure of maintained paved Federal Roads

The factors which are essential in this case are depicted in Table 4-15 below.

Table 4-15: The rank of general causes that affect the maintained Roads

No.	General Causes	Average Index	Rank
1	Quality of work	4.13	8
2	Required cost	4.56	5
3	Required period	4.00	12
4	Quality of design	3.94	13
5	Working load	4.81	1
6	Workers' skill	4.81	1
7	Data inventory and Data base	3.38	14

8	Heavy Traffic	3.13	15
9	Maintenance Culture	2.00	16
10	Highway Amenities	1.50	17
11	Laboratory and Insitu Tests on Soil	4.19	7
12	Quality Materials	4.75	3
13	Supervision	4.06	11
14	Knowledge Base	4.13	8
15	Weather Condition	4.69	4
16	Drainage supply	4.13	8
17	Soil Condition	4.56	5
18	Others	1.00	18

Source: Field survey data on October 20, 2017

As shown in Table 4-15 above, the majority of the factors are in the cause and major cause category. It is further shown that the respondents ranked the major cause (above 4.55 average index) which affect the failure of maintained paved road networks as follows:

i. Workers' skill
ii. Working load.
iii. Quality of materials.
iv. Weather Condition.
v. Soil Condition.
vi. Required cost.

The respondents identified the causes which included: 'Laboratory and Insitu Tests on Soil', 'Quality of work', 'Knowledge Base', 'Drainage supply', 'Supervision', 'Required period' and 'Quality of design' based on the average index between 3.55 and 4.55. Therefore, the contractor should take care of these causes.

4.4.3.2 Factors affecting timely completion of maintained Road Project

The participants ranked the factors that delay Maintenance Road Project Completion within Scheduled Time as shown in Table 4-16 below. The majority of the respondents ranked the causes as follows:

i. Uneven increase/fluctuation of material price.

ii. Shortage of material and manpower.

iii. Extreme site condition like rain, flood, etc..

iv. Lack of technical personnel at client (ERA).

v. Lack of efficient/competent contractor.

vi. Modification of plan or design on related issues.

vii. Knowledge and planning.

viii. Dependency on donor funding.

In addition, Table 4-16 shows that the fluctuation of prices of the construction materials and shortage of materials including shortage of skilled manpower are the major causes which delay the completion of maintenance projects. If the maintenance takes longer than planned, the road deterioration could be high. Extreme site condition and delays in payment to the contractor affects timely completion of maintenance projects. Lack of efficient/competent contractors results in failures of maintenance projects due to the monopoly by few qualified contractors.

All the causes stated in table 4-16 are related to each other. Therefore, these causes need proper attention by the concerned contractor and client to safeguard maintained paved roads which should be robust and conducive to the end users.

Table 4-16: Causes that delay maintenance Roads to complete within scheduled time

Causes	**Ranked by number of respondent**	**Rank**
Uneven increase/fluctuation of material price	14	1
Shortage of material, manpower	10	2
Extreme site condition like rain, flood etc.	2	3
Lack of expert technical personnel by client (ERA)	9	4
Modification of plan or design related issues	7	5

Extra work requirements of contractors	15	6
Knowledge and planning	7	7
Dependency on donor funding	8	8
Contract disputes or issues between the parties	11	9
Inadequate government support	8	10
Need for experienced large sized contractor	8	11
Slow administrative process by client (government/ERA)	8	12
Political influence	13	13

Source: Field survey data on October 20, 2017

4.4.3.3 Quality Related Factors

This section has five questions on the quality of work related to road maintenance by using a five point of Likert scale and the results are presented in Table 4-17 below.

Table 4-17: The responses on quality of maintenance work

No.	Quality related factors	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Material quality control on the maintenance road are sufficient.	25	56.25	18.75	0	0
2	The existing quality control policies that addresses all quality control issues are enough.	0	43.75	37.5	18.75	0
3	The amount of resource allocated for implementing quality objectives are sufficient.	6.25	75	18.75	0	0
4	The current contracting process lacks or restricts contractor from introducing new technology	0	0	18.75	75	6.25
5	The supervisory staffs' efficiency in achieving road maintenance project goal is sufficient.	62.5	37.5	0	0	0

Source: Field survey data on October 20, 2017

The majority of the respondents (56.25%) disagreed on the material quality control 25% strongly disagreed, and 18.75%) neither agreed nor disagreed on the sufficiency of material quality control on maintenance of roads.

As shown in Table 4-1743.75% of the respondents disagreed on the existing quality control policies that addresses all quality control issues are enough while only small number of respondents agreed on the existing quality control policies that addresses all quality control issues are enough. The other group of respondents (37.5%) marked them neutral on the statement of the existing quality control policies that addresses all quality control issues are enough.

Most of the respondents (81.25%) stated that the amount of resource allocated for implementing quality objectives are insufficient. The remaining 18.75% marked themselves as neutral. Table 4-17 further presents that 81.25% of the respondents believed that the current contracting process lacks or restricts contractors from introducing new technology and the remaining participants neither agreed nor disagreed on the statement. All participants disagreed on the statement of the supervisory staffs' efficiency in achieving road maintenance project goal.

Therefore, the quality of work on maintenance road, according to the participants of contractors, can be concluded that the levels of quality achieved on the maintained paved road that is; material quality controls; existing quality control policies that addresses all quality control issues, amount of resource allocated for implementing quality objectives, flexibility of contracting method that introduce technology and supervisory staffs' efficiency are insufficient.

4.4.3.4 Risk sharing related factors

In this case, the respondents explained their ideas in two statements in five scale of Likert indicators as depicted in Table 4-18 below.

Table 4-18: The responses on risk sharing in road maintenance projects

No.	Statements	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Client has to take all the responsibilities of the project	0	0	18.75	68.75	12.5
2	Road maintenance construction project risks should be properly identified and shared between the contractor and the client	6.25	87.5	6.25	0	0

Source: Field survey data on October 20, 2017

As stated in Table 4-18 above, almost all of the respondents (91.25%) agreed with the statement that the client has to take all the responsibilities of the projects; whereas, the remaining 18.25% of respondents stood neutral on the statement. On the other hand, 93.75% of the respondents disagreed that road maintenance construction project risks should be properly identified and shared between the contractor and the client.

Therefore, it can be concluded that contractors believe that the client has to take all the responsibilities of the road maintenance projects suggesting the client should take the responsibility in proper identification of risks. However, the principle that contractors should share the responsibility to get properly identified risks which improves the sustainability of maintained road is beneficial to road users as well as to the nation.

4.4.3.5 Cost in execution of Maintenance road project

Table 4-19 above illustrates that 43.75% of the respondents neither agreed nor disagreed on the current contracting method to reduce maintenance costs during the contract duration, while 25% of them disagreed on the statement. Conversely, 31.25% of the respondents agreed that the current contracting method will reduce maintenance costs during the contract duration. The majority of the respondents (68.75%) believed that the nature of current contracting method mainly focuses on user satisfaction; but the remaining 31.75% neither agreed nor disagreed on the statement. Therefore, there are still problems on use of the current contracting method to reduce the maintenance cost and to increase user satisfaction. Because of this, the maintenance work has quality and sustainability difficulties.

Table 4-19: The percentage of responses regarding cost in contract method

No.	Statement	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Current contracting method will reduce maintenance costs during the contract duration	0	25	43.75	31.25	0
2	The nature of current contracting method mainly focuses on user satisfaction	18.75	50	31.25	0	0

Source: Field survey data on October 20, 2017

4.4.3.6 Technical feasibility Barriers in maintenance roads

The questionnaire survey in this case was to identify the technical capability of the ERA in managing better-quality maintenance roads. Table 4-20 illustrates the percentages of responses on the technical feasibility barriers in road maintenance.

Table 4-20: The technical feasibility and Barriers in maintenance roads

No.	Statement	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	ERA has good contracting management experience and can easily adopt the current contracting method concept	0	25	50	25	0
2	ERA has good knowledge and data of road networks, maintenance needs and costs which can be used to implement	81.25	18.75	0	0	0
3	Lack of government's budgetary allocation for the long-term commitment could be a problem	0	0	18.75	68.75	12.5

Source: Field survey data on October 20, 2017

Table 4-20 above presents that 25% of the respondents agreed and 25% disagreed that ERA has good contracting management experience and can easily adopt the current contracting method concept. The remaining half of the respondents stood neutral. All of the respondents

disagreed that the ERA has good knowledge and data of road networks, maintenance needs and costs which can be used for implementation. In this regard, most of the respondents (81.75%) believed that there is lack of government's budgetary allocation for the long-term commitment and the remaining respondents neither agreed nor disagreed on this statement.

Therefore, it can be concluded that ERA lacks knowledge and data of road networks, maintenance needs and maintenance project costs and also lack budgetary allocation to manage the maintenance implementation of road projects.

4.4.3.7 Sufficiency of funding road maintenance

In Figure 4-14, presents the respondents' responses on the sufficiency of funding for road maintenance projects provided by government. The majority of respondents (81%) stated that half of the funds requested for work were provided by the Government while 13% of respondents indicated that very little funding is provided. Other small group of participants stated all funding requested for work are provided. Therefore, this section can be concluded that getting fund for maintenance is a challenging issue in the ERA. This hampers the road maintenance works, especially routine maintenance.

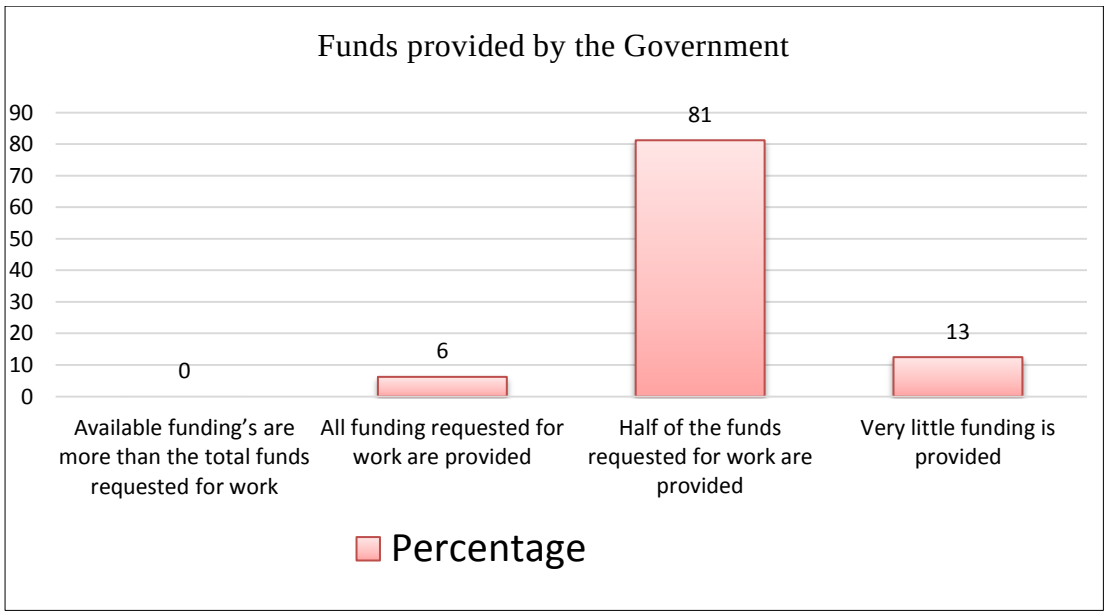


Figure 4-18: The responses on the sufficiency of funding

4.4.3.8 Appropriate Drainage facility in Maintained road

In this case, the questionnaire was distributed to the participants in this section to investigates the existence and the problems of deterioration.

a. Existence of appropriate drainage facility

Figure 4-15 below shows the respondents opinion on the existence of drainage facility and appropriateness in maintained paved Federal road.

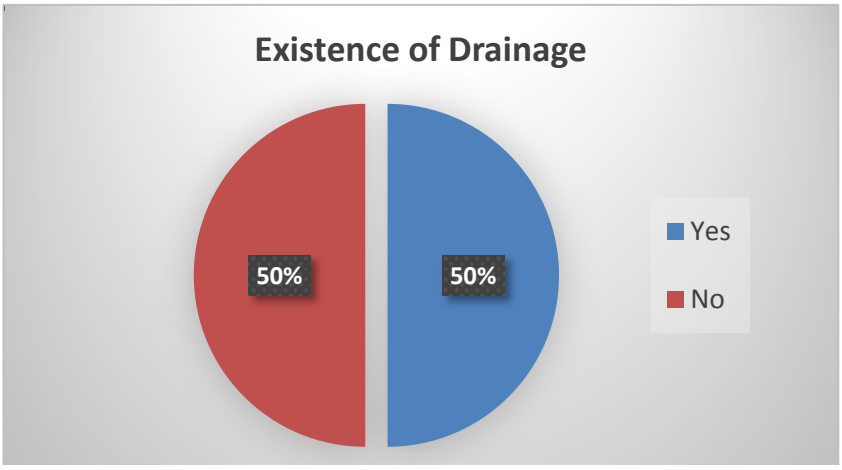


Figure 4-19: Theexistence of drainage facility and appropriateness

Half of the respondents replied that there is existence of drainage facility on maintained road while 50% of respondents believed that there is lack of drainage facilities. All the respondents cited that there were inadequate designs, lack of enough studies to establish the drainage requirements of the road and poor workmanship as a result of corruption.

b. Causes for drainage facility deteriorate

The objective of this section is to obtain the major factors that cause the existing drainage facility to deteriorate. Figure 4-16 illustrates that the respondents' opinion on the causes for drainage facility deteriorate maintained paved Federal roads.

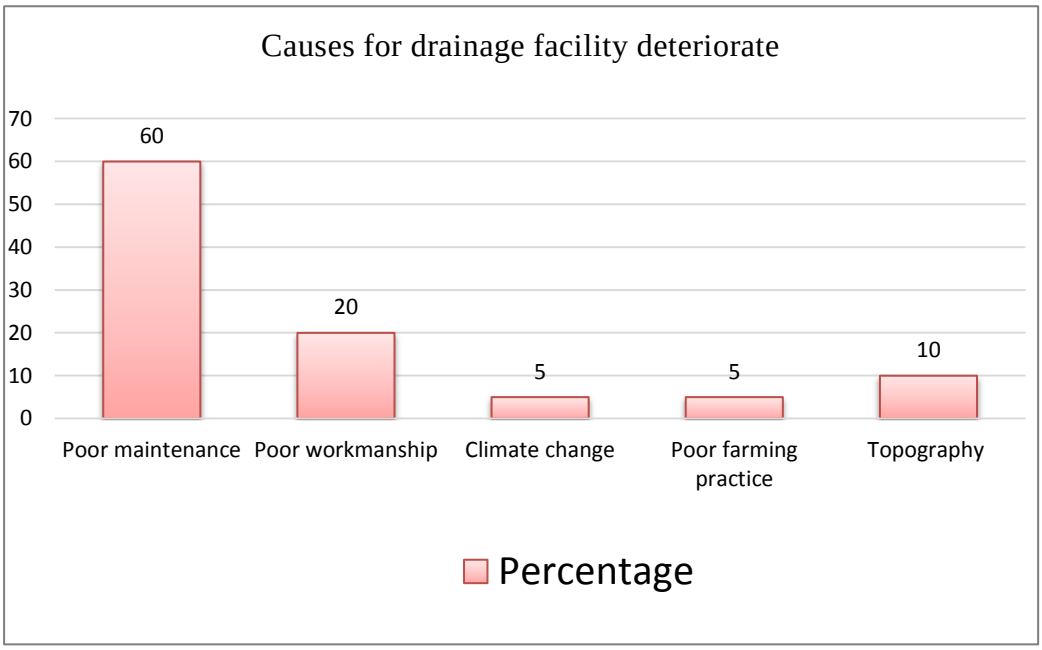


Figure 4-20: The responses on causes for drainage facility deteriorate

The majority of the respondents (60%) believed that the poor maintenance can affect the appropriateness of the drainage facilities. In addition to this, 20% of the respondents stated that poor workmanship is the cause for the deterioration of drainage facilities. All agreed that though there was a need to carry out maintenance on the existing drainage facilities to increase their efficiency and effectiveness. They stated that redesigns and reconstruction have not been implemented, due to lack of resources and commitment by the government. Farming practices in the area according to the contractors cannot be blamed for the erosion of the road and drainage features but instead the small capacity of the drainage system provided. Therefore, the lack of appropriate drainage in maintained road is one of the causes of frequent failures of those maintained paved Federal roads.

4.4.4 CONSULTANTS PERCEPTION

The objective in this section is to investigate and discuss the results generated from the responses of the questionnaires distributed to consultants who work with contractors on Federal road maintenance which identify the causes for frequent failure of maintained paved Federal road networks.

4.4.4.1 The general factors that deteriorate the maintained paved Federal roads

The respondents ranked the factors that cause failures of maintained paved roads. The factors and rankings are presented in in Table 4-21 below.

Table 4-21: The general causes that affect the maintained paved Federal Roads

No.	General Factors	Average	Rank
1	Quality of work	4.1	8
2	Required cost	4	9
3	Required period	3.9	11
4	Quality of design	4.7	4
5	Working load	4.7	4
6	Workers' skill	4.8	1
7	Data inventory and Data base	3.1	14
8	Heavy Traffic	3	15
9	Maintenance Culture	1.8	16
10	Highway Amenities	1	17
11	Laboratory and Insitu Tests on Soil	4	9
12	Quality Materials	4.8	1
13	Supervision	3.9	11
14	Knowledge Base	4.5	7
15	Weather Condition	3.7	13
16	Drainage supply	4.8	1
17	Soil Condition	4.7	4
18	Others	1	17

Source: Field survey data on October 20, 2017

Table 4-21 above shows that the respondents ranked the major cause (above 4.55 average index) which affect the failure of maintained paved road networks as follows:

i. Workers' skill
ii. Quality materials
iii. Drainage supply
iv. Quality of design
v. Working load
vi. Soil Condition

The respondents identified the causes which include 'Knowledge Base', 'Quality of work', 'Required cost ', Laboratory and Insitu Tests on Soil', 'Supervision', 'Required period', and 'Weather Condition' based on the average index which scored between 3.55 and 4.55. Therefore, the consultant identified these factors and suggested that the client and contractor should take care of these factors which are the major causes of frequent failures of maintained federal roads.

4.4.4.2 Factors affecting Scheduled Time

Table 4-22 below shows respondents' rankings based on the causes for delay to complete the maintenance road construction projects including uneven increase/fluctuation of material price; shortage of material, manpower; extreme site condition like rain, flood etc.; knowledge and planning; lack of expert technical personnel by client (ERA); extra work requirements of contractors; modification of plan or design related issues and dependency on donor funding.

Table 4-22 above shows the fluctuation of the prices of the construction materials, shortage of materials, manpower; extreme site condition like rain, flood etc. and knowledge and planning are the main causes delays in the accomplishment of maintenance projects. If the maintenance takes longer time, the road deterioration could be high. Modification of design and dependency on donor funding also adversely affects road maintenance activities. All causes as revealed in Table 4-22 are equally related to each other. Therefore, these causes need proper attention from the contractor and client to safeguard the effective maintence of paved roads which should be durable and conducive to the end users.

Table 4-22: The participants ordered the factors that extend maintenance road project

Causes	Ranked by number of respondent	Rank
Uneven increase/fluctuation of material price	3	1
Shortage of material, manpower	5	2
Extreme site condition like rain, flood etc.	5	3
Knowledge and planning	4	4
Lack of expert technical personnel by client (ERA)	5	5
Extra work requirements of contractors	6	6
Modification of plan or design related issues	4	7
Dependency on donor funding	5	8
Contract disputes or issues between the parties	4	9
Inadequate government support	3	10
Need for experienced large sized contractor	3	11
Slow administrative process by client (government/ERA)	5	12
Political influence	7	13

Source: Field survey data on October 20, 2017

4.4.4.3 Quality Related Factors

This section has five questions on the quality of work attained in road maintenance by using a five point of Likert scale and the results are presented in Table 4-23 below.

In Table 4-23, it is presented that 90% of the respondents disagree on the material quality control on the maintenance road are sufficient while 10% of respondents are marked them neutral. The majority of respondents (80%) considered that the amount of resource allocated for implementing quality works are not enough. Only 20% of the respondents neither disagreed nor agreed on the statement. Similarly, half of respondents (50%) disagreed on the existing quality control policies that addresses that all quality control issues are enough while the remaining half neither agreed nor disagreed. Table 4-23 further presents that half of

respondents believed that the current contracting process lacks or restricts contractors from introducing new technology while 20% of the respondents agreed on the statement and the remaining 30% of the respondents neither agreed nor disagreed on the current contracting process lacks or restricts contractors from introducing new technology. All of the respondents disagreed on the statement of supervisory staffs' efficiency in achieving road maintenance project goal is sufficient.

Therefore, quality of work on the maintenance road according to the participants of consultants can be concluded that the levels of quality achieved on the maintained paved road; existing quality control policies that addresses all quality control issues, amount of resource allocated for implementing quality objectives, flexibility of contracting method that introduce technology and supervisory staffs' efficiency are insufficient.

Table 4-23: The responses on quality of maintenance work

No.	Quality related factors	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	Material quality control on the maintenance road are sufficient.	40	50	10	0	0
2	The existing quality control policies that addresses all quality control issues are sufficient.	0	50	50	0	0
3	The amount of resource allocated for implementing quality objectives are enough.	0	80	20	0	0
4	The current contracting process lacks or restricts contractor from introducing new technology	0	20	30	50	0
5	The supervisory staffs' efficiency in achieving road maintenance project goal is sufficient.	60	40	0	0	0

Source: Field survey data on October 20, 2017

4.4.4.4 Risk sharing related factors

Risk sharing related factors in this section describes the suggestion of consultants if contractors and clients were taking any responsibility for poor works on maintenance on

roads. The respondents described their ideas in five indicators of Likert scale and are presented in Table 4-24 below.

Table 4-24: The responses on risk sharing in road maintenance projects

No.	**Statements**	**Strongly disagreed**	**Disagreed**	**Neutral**	**Agreed**	**Strongly agreed**
		%	%	%	%	%
1	Client has to take all the responsibilities of the project	10	30	20	50	0
2	Road maintenance construction project risks are properly identified and shared between the contracting party.	10	60	30	0	0

Source: Field survey data on October 20, 2017

As presented in Table 4-24 above, half of the respondents (50%) agreed with the statement that the client has to take all the responsibilities of the projects, whereas 40% of respondents disagreed with the statement. A small group of the respondents (20%) stood neutral on the statement. On the other hand, the majority of respondents (70%) disagreed that road maintenance construction project risks are properly identified and shared between the contracting party while no one either agreed or strongly agreed with the statement. The remaining 30% of the respondents neither agreed nor disagreed with the statement of road maintenance construction project risks are properly identified and shared between the contracting party.

Therefore, it can be summarized that the contracting party has to share responsibilities to understand and acquire properly identified risks which improve the maintenance of roads and will be valuable and robust to the end users as well as the nation.

4.4.4.5 Efficiency improvement of Maintenance road project

As presented in Table 4-25 below, the majority of the respondents (70%) strongly agreed that the current contracting method will reduce maintenance costs during the contract duration while only 10% disagreed on the statement. On the other hand, 20% of the respondents stood neutral.

Table 4-25: The percentage of responses regarding efficiency

No.	Statement	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	The current level of efficiency regarding road maintenance by ERA staff needs improvement	0	10	20	10	60
2	The current status of maintained paved Federal road need improvement regarding road maintenance project by ERA	0	10	30	60	0

Source: Field survey data on October 20, 2017

More than half of respondents (60%) believed that the current status of maintained paved Federal road need improvements; whereas 10% of respondents disagreed on the statement and the remaining 30% neither agreed nor disagreed on the statement. Therefore, there is still a problem on the current level of efficiency and maintained road suitability. Due to the, the increase in the maintenance costs, user satisfaction and national interest will be adversely affected. Because of this, the maintenance work has quality and sustainability problems.

4.4.4.6 Technical feasibility barriers of maintenance roads

Table 5-26 below presents the percentages of responses on the technical feasibility barriers in road maintenance.

Table 4-26: The technical feasibility and Barriers in maintenance roads

No.	Statement	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
		%	%	%	%	%
1	ERA has good contracting management experience and can easily implement the current contracting method concept	0	40	20	40	0
2	ERA has good knowledge and data of road networks, maintenance needs and costs which can be used to implement	10	60	30	0	0

3	Lack of government's budgetary allocation for the long-term commitment could be a problem	0	30	10	40	20

Source: Field survey data on October 20, 2017

According to Table 4-26, 40% of respondents agreed with the statement of ERA has good contracting management experience and can easily adopt the current contracting method concept while 40% of the respondents disagreed on it and the remaining 20% stood neutral. Most of the respondents (70%) disagreed that the ERA has good knowledge and data of road networks, maintenance needs and costs which can be used to implement but no one agreed on the statement. The remaining 30% of the respondents neither agreed nor disagreed with the statement that the client has good knowledge and data of road networks, maintenance needs and costs which can be used to implement. In addition, Table 4-26, illustrates that the majority of respondents (60%) believed that there is lack of government's budgetary allocation for the long-term commitment while 30% of respondents disagreed.

Therefore, it can be summarized as client knowledge on maintenance road and data of maintenance road networks and lack of fiscal allocation are barriers to implement the maintenance of roads.

4.4.4.7 Sufficiency of funding for road maintenance

The results of the survey in this regard is depicted in Figure 4-17 below stating that responses on the adequacy of funding for road maintenance projects provided by government. The figure illustrates that the majority of respondents (70%) stated that half of the funds requested for work were provided by government whereas 20% of respondents expressed that very little funding was provided and 10% of the respondents stated that all funding requested for works were provided.

Therefore, it can be summarized that getting fund for maintenance is a challenging issue in Ethiopia. This hinders the road maintenance works; especially routine maintenance will be slowed and increases in poor condition of the maintained paved federal road network.

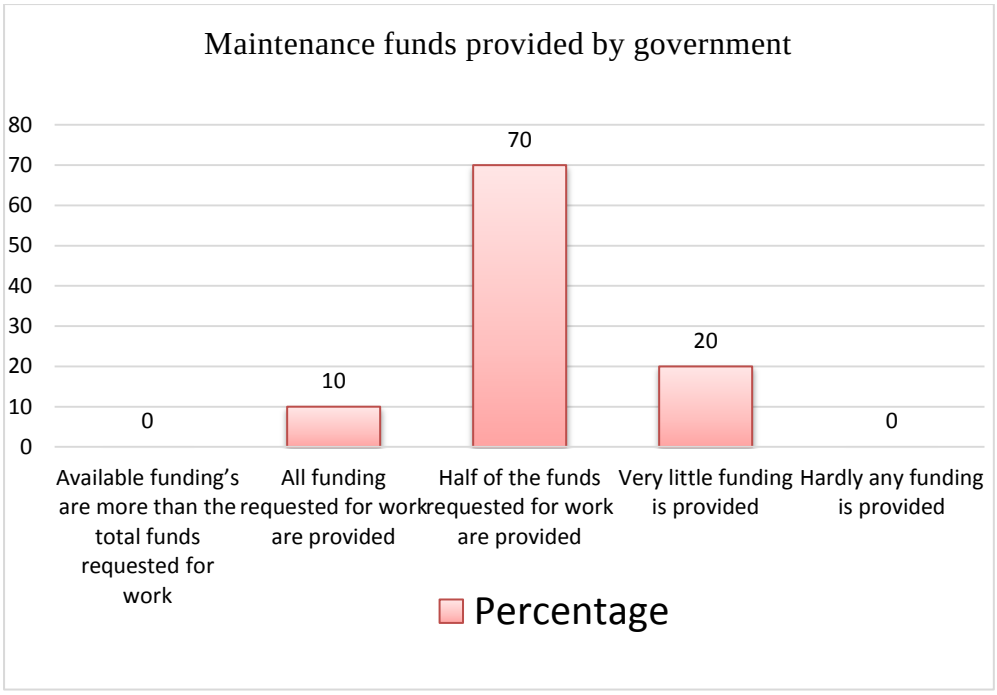


Figure 4-21: The responses on the sufficiency of funding

4.4.4.8 Appropriate drainage facilities in maintained roads

This questionnaire survey results discusses the existing drainage facilities are proper and active in maintained paved road. The questionnaire survey distributed to the participants in this section explores the existence and the cause of problems for deterioration.

a. Existence of appropriate drainage facility

Figure 4-18 below shows the respondents' opinion on the existence of drainage facilities and appropriateness in maintained paved Federal road.

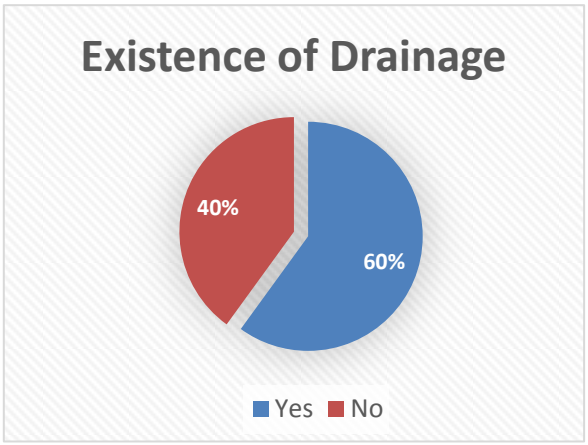


Figure 4-22: The existence of drainage facility and appropriateness

The majority of the respondents (60%) responded that there is drainage facility on maintained road while 40% believed that there is lack of drainage facilities and appropriateness.

b. Causes of drainage facility deterioration

Figure 4-19 illustrates the respondents' opinion on the causes of drainage facilities and deterioration of maintained paved Federal roads. The figure presents that the majority of the respondents (70%) considered that the poor maintence can affect the appropriateness of the drainage facilities; 20% of respondents described that topography is the cause for the deterioration of drainage facilities and all decided that it could be essential to carry out maintenance on the existing drainage facilities to enhance the serviceability. As conclusion, all the respondents believed in inadequacy of drainage facilities, lack of enough observation to establish the drainage requirements of the road and poor workmanship as a result of corruption. Therefore, the lack of appropriate drainage in the case of maintained road is one of the causes for frequent failure of the maintained paved Federal roads. Figure 4-19 below shows the cause of drainage facility deterioration.

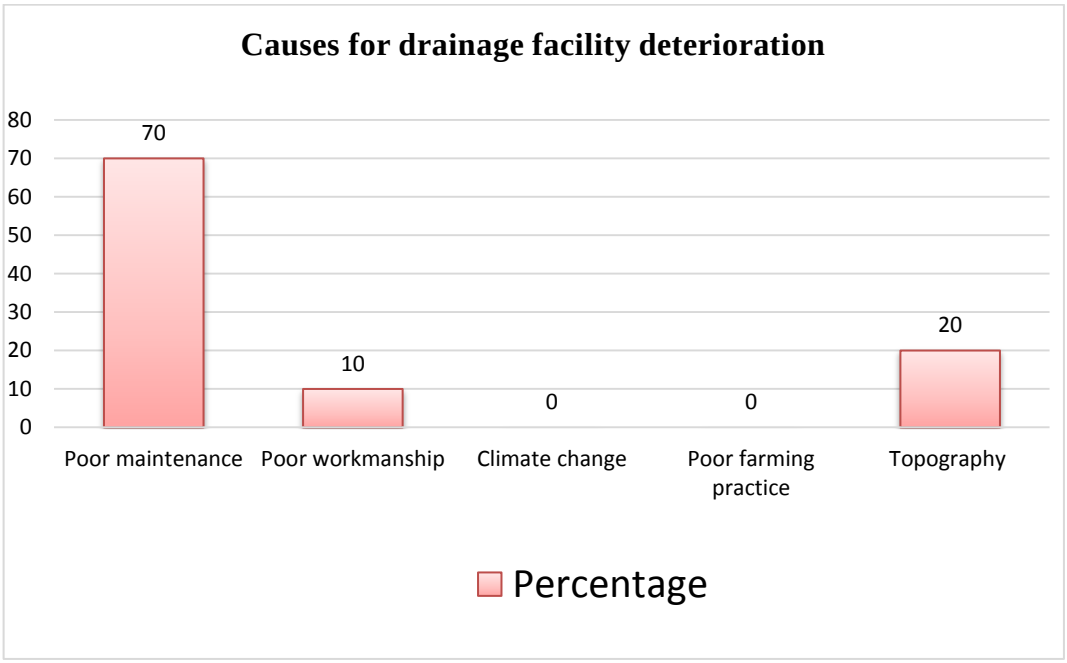


Figure 4-23: The causes for drainage facility deterioration of roads

4.4.5 MAINTAINED ROAD USERS PERCEPTION

Road users were asked to recall the most recent trip they made using maintained road and provided details about the journey. This included the time, distance and experiences on the journey. Maintained paved Federal road overall satisfaction score is derived from five core areas of user experiences: journey time; safety; information/signage; roadworks management; and general upkeep of the road.

4.4.5.1 Responses from Maintained Paved Road Users

Road users were asked to recall the most recent trip they made using newly maintained paved road and they provided details about their journeys. These included: time, distance and experiences on the journey. Maintained paved Federal road overall satisfaction score were derived from five core areas of user experiences: journey time; safety; information/signage; road works management; and general upkeep of the road.

4.4.1.2 Responses from Maintained Paved Road Users

Figure 4-20 presents that the majority of the respondents (73%) traveled on recently maintained paved Federal road more than 10 times while no one did travel less than three times. The data collected shows that 27% of the respondents traveled between 4-9 times. This was vital to the research as it presented the fact that the respondents could be trusted to provide reliable information to achieve the study's objectives. It also explained that the users had understood the maintained road conduciveness and its effect.

The road users were concerned about their safety and the convenience of going through maintained paved road due to the severity of the maintained road condition, the travel frequency between particular place was restricted. Figure 4-21 below illustrates that the majority of the respondents (70%) stated that the travelling time increased between particular places whereas only a small group of respondents (10%) answered that travelling time decreased between particular places. The remaining 20% of the respondents stated that travelling time neither increased nor decreased between particular places.

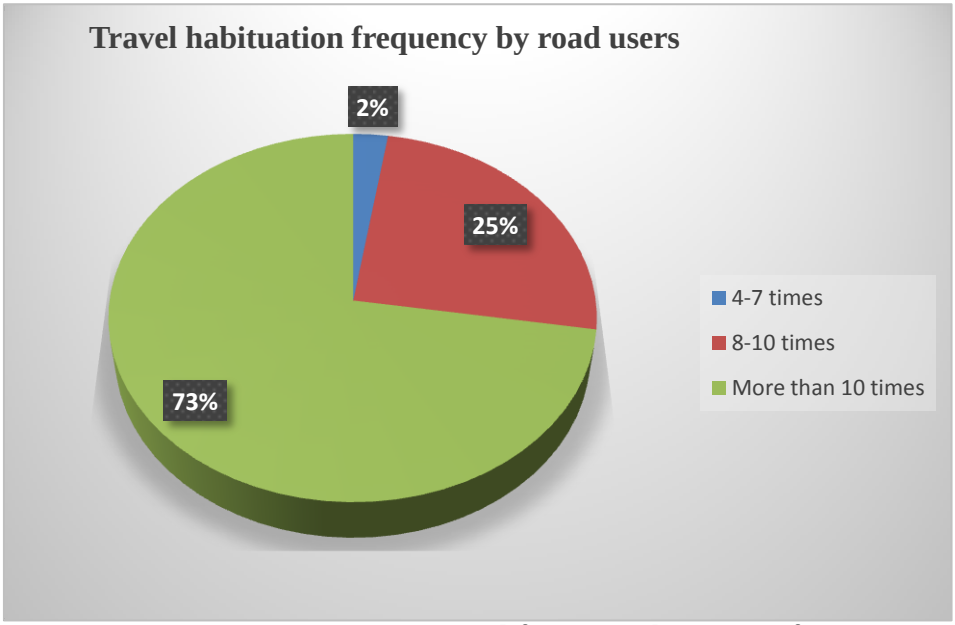


Figure 4-24: Travel frequency by usage of MRU

Therefore, minimizing travel-time was a major concern, and considered that spent time was 'dead time' in which other activities could not be pursued simultaneously. The results have investigated that increase in travel times have adversely affected road user satisfaction.

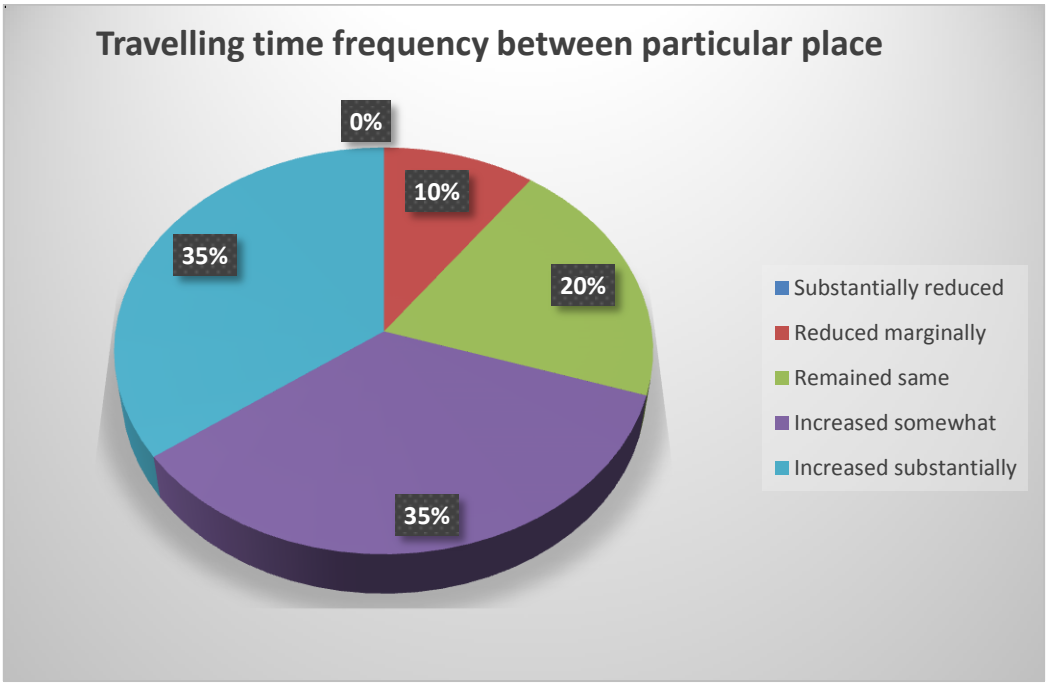


Figure 4-25: Traveling time frequency between particular places by MRU

The state of frequently failed maintained road affects fuel consumption. As shown in the Figure 4-25 below, most of the respondents (80%) stated that fuel consumption increases due to failure of maintained paved Federal road while 12% of the respondents replied that fuel consumption

decreased modestly. Only a small group of respondents expressed no change on fuel consumption as a result of maintained road. The deteriorated condition of maintained road also affected the overall maintenance cost of the vehicles. Therefore, this increase in fuel consumptions on maintained road imply that the state of the road is in poor condition and it needs follow-up and effective maintenance.

4.4.5.2 Causes of maintained paved road on the basis of Road Users Responses

The respondents ranked the factors attributed to recurrent failures of maintained paved roads as stipulated in Table 4-27 below.

No.	General Factors	Average Index	Rank	Scale
1	Quality of work	4.1	3	Cause
2	Required cost	3.55	9	Cause
3	Required period	3.85	6	Cause
4	Workers' skill	3.92	4	Cause
5	Heavy Traffic	3.65	8	Cause
6	Maintenance Culture	4.12	2	Cause
7	Quality Materials	4.35	1	Cause
8	Knowledge Base	3.42	11	Neutral
9	Weather Condition	3.48	10	Neutral
10	Drainage supply	3.89	5	Cause
11	Soil Condition	3.8	7	Cause
12	Others	0.1	12	Not cause

Table 4-27: Indexes, ranks and scales of causes that adversely affect the Roads

Source: Field survey data on October 20, 2017

As shown in Table 4.27 above, most of the factors cause road failures. The respondents ranked the causes and the average indexes were calculated between 3.55 and 4.55. The factors were prioritized as follows.

i. Quality of materials
ii. Maintenance culture
iii. Quality of work
iv. Workers' skill
v. Drainage supply
vi. Required period

Therefore, the road users concluded that the concerning body should provide the required attention on factors that that cause frequent failure of maintained Federal roads.

In addition, the responses were ranked using the Five-points Likert scale as illustrated in Table 4-28 below.

Table 4-28: Ranks of factors based on road safety and convenience

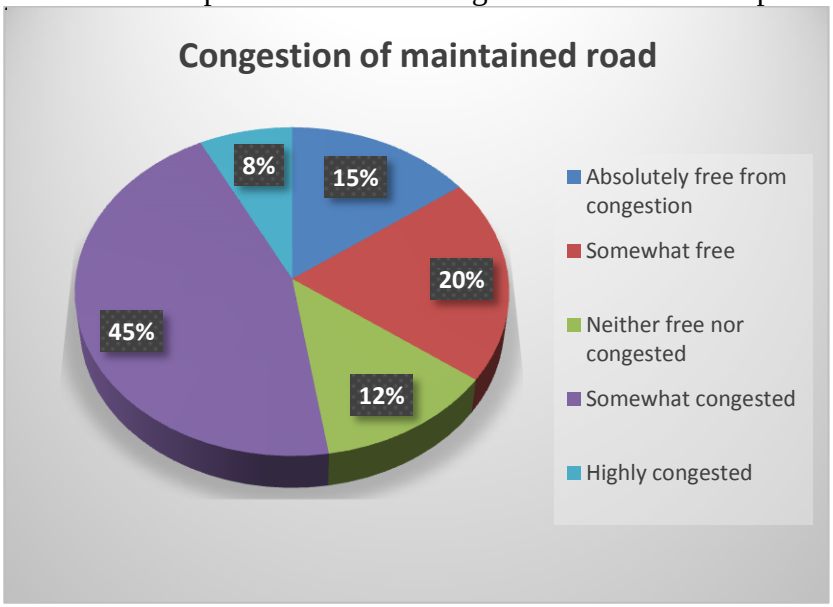
No.	General Factors	Average Index	Rank	Scale
1	Quality of road markings on these roads (such as painted lines, reflection signs, pedestrian crossing markings, etc)	3.075	8	Neutral
2	Adequacy of warning / road signs	2.45	6	Poor
3	Visibility of warning/ roads signs during day and night	2.575	7	Neutral
4	Positioning/ location of warning / road signs	2.25	4	Poor
5	Adequacy of milestones / distance signs	2.35	5	Poor
6	Visibility of milestones / distance signs	2.2	3	Poor
7	Availability of streetlights on these roads	2	2	Poor
8	Conducive surface texture of road.	1.8	1	Poor

Source: Field survey data on October 20, 2017

The safety features on the maintained paved road is the major issue for conducive environment to the users. Table 4-28 presents that almost all the respondents ranked their responses in poor status. They ranked first the conducive surface texture of maintained paved road. Availability of streetlights was ranked second and visibility of milestones / distance signs was ranked third due severity of condition. The surfaces of the maintained roads were not safe and convenience. Thus, the maintenance method

must check these and other mentioned factors. Figure 4-26 below shows the percentages of response on traffic congestion of the maintained paved road.

Figure 4- 26: The responses on traffic congestion of maintained paved road



Maintained paved Federal road could be overcrowded or congested in traffic. More than half of participants (53%) believed the maintained paved Federal road were congested and the carrying capacity was more than expected while more than one-third (35%) of the participants believed that the road is free from traffic congestion. The remaining 20% of the participants expressed neither free nor congested. Hence, the causes of failures of maintained road is congestion by overcapacity vehicles.

As presented in in Figure 4-24, the majority of respondents described that the quality of maintained road-surface, road-smoothness and surface-appearance is in poor condition whereas only a small group of participants responded otherwise. 22.5% of the participants stated neither good nor poor. Therefore, it can be summarized that the surface treatment of maintained paved road need improvement to provide reasonable services to road users. Figure 4-28 below provides percentages of responses on maintained road surface quality.

Figure 4-27:The responses on maintained road surface quality

As discussed above regarding safety features and convenience of maintained paved road, the respondents gave their opinions on road safety as presented in Figure 4-25 below. Most of the respondents (82.5%) stated that the maintained road is not safe. Out of the 82.5% of the respondents, 62.5% responded very unsafe and the remaining 17.5% stated neither safe nor unsafe.

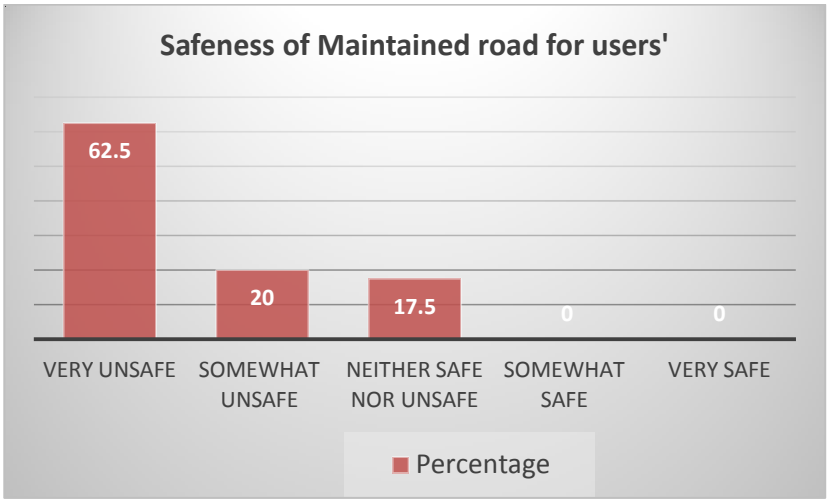


Figure 4-28: The responses on conduciveness of maintained paved road for users'

Table 4-28 below indicates why road users feel that maintained paved roads are unsafe. The participants have ranked the features in respect of safety as follows:

- Unsafe retaining walls;
- Absence of plantation at places prone to land sliding;
- High volume of traffic;

- Bad weather;
- Sharp turns; and
- Absent/ loose parapets.

Therefore, the respondents suggested that the concerned bodies should take care of these structures. Table 4-28 below shows rankings of factors for road safety.

Table 4-29: The respondents' impression of users on maintained paved road unsafe

No	Factors	Frequency	Percentage	Rank	No		Frequency	Percentage	Rank
1	High volume of traffic	25	9.65	3	7	Bad weather	25	9.65	3
2	Heavy vehicles	21	8.11	8	8	Absence of streetlights	23	8.88	7
3	Poor/ aggressive driving	20	7.72	9	9	Sharp turns	24	9.27	5
4	Absent/ loose parapets	24	9.27	5	10	Bad signage	19	7.34	10
5	Unsafe retaining walls	31	11.97	1					
6	Absence of plantation at places prone to land sliding	28	10.81	2					

Source: Field survey data on October 20, 2017

Figure 4-26 below presents the percentages of responses on condition of maintained paved road by drainage facility. The majority of the respondents (58%) considered that the condition of drainage was in poor condition whereas 17% expressed that the state of drainage is in good condition and 25% believed that the drainage condition was fair.

Thus, the damage on the road was severe and the road surfaces were washed away due to the poor state of drainage facility. This showed that road users were exposed to accidents and so needed a move to correct the drainage system. As to drainage facilities, the respondents responded that it was not with enough capacity to satisfactorily drain water during a heavy rainstorm. Due to the poor condition of drainage, the maintained paved road frequently failed. Figure 4-26 below shows percentages of responses on condition of maintained paved road drainage facility

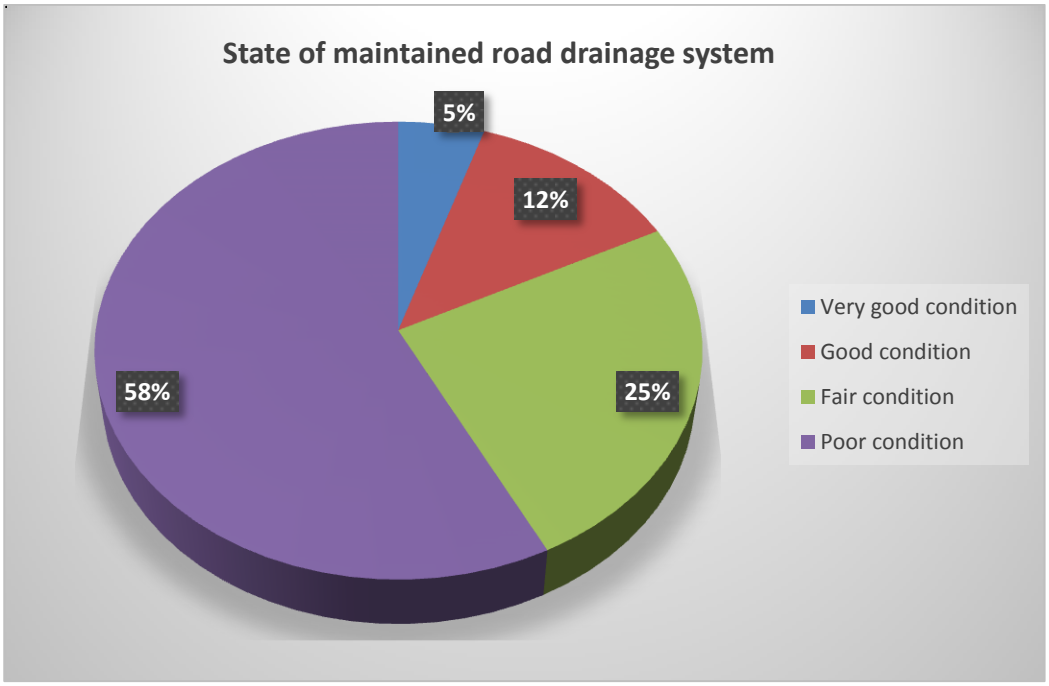


Figure 4-29: The response on condition of maintained paved road drainage facility

It was also find out how poor drainage affect both the maintained paved federal road and the users and is presented in Figure 4-27 below. In this regard, maintained paved road users agreed on adverse effects of poor drainage to road users. The majority the respondents (63%) stated that runoff cuts through the road during the rains hindering free movements of vehicles on the road by blocking the road. It also washed away bridges totally making passage impossible. Twenty-five (25%) of the respondents expressed that the runoffs cut through the road and leave debris on the road after the rains; this debris would then hinder movement along the road and therefore creates inconvenience to travelers. The travelers would then become late in their businesses or other engagements.

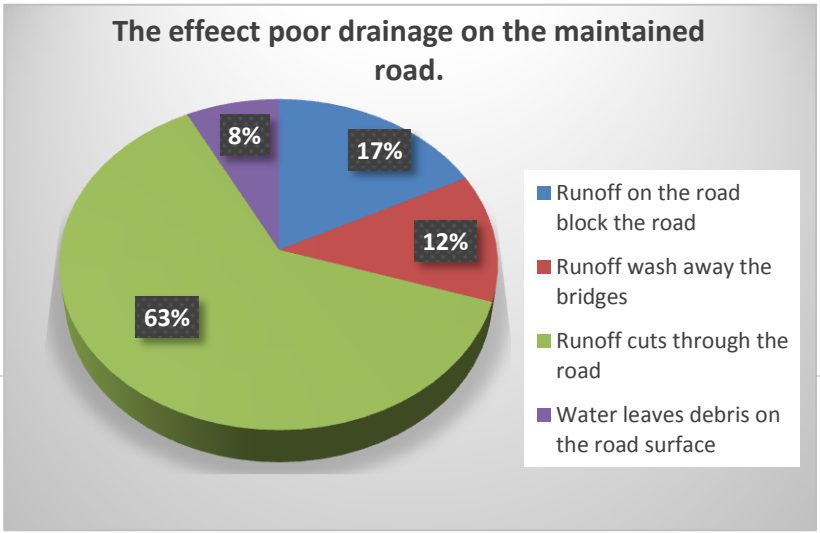


Figure 4-30: The response on effect of poor drainage

From the data illustrated in Figure 4-28 below, there is a clear indication that the majority of the road users (75%) were not satisfied with the condition of maintained paved Federal road. Therefore, there is a need to improve the maintenance culture and methods in order to satisfy road users.

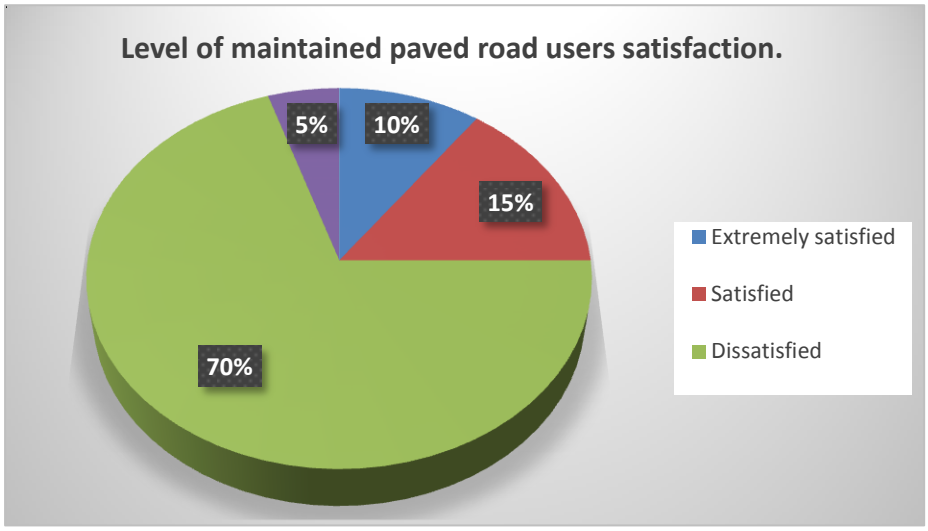


Figure 4-31: The responses on level of maintained road users' satisfaction

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

This study was concerned with the major factors that affect maintained Asphalt pavement Federal road and to investigate the condition of maintenance road under the Central District of the ERA using annual project report, maintenance manual, maintenance specification and selected segments whether the existing maintenance pavement was good or not based on serviceability. It is obvious that good maintained road is fundamental in the provision of a good road network system and satisfy of end users.

The visual condition of maintained road explained the physical distress of maintained asphalt pavement and their effect on end users. In every maintenance situation, safety and accessibility are important considerations for road users, including drivers who use the roads.

Based on the results of the questionnaire survey, the major causes of failures of maintained paved road are deficiency in workers' skill, maintenance culture, quality materials and soil condition; uneven increase/fluctuation of material price, shortage of material, manpower and lack of efficient/competent contractor and not taking responsibility of risks that happen pre- and-post of maintenance works. And also, lack of evaluation method of the pavement for structural, functional and safety of maintained road condition and maintenance treatment selection techniques are also the cause for maintained paved road failure and increase in travel time, increase in consumptions of fuel on maintained road imply that the state of the road is in poor condition

In addition to the above, the basic reasons for deteriorated maintenance road in Ethiopia include; inadequate feasibility studies to ascertain the maintenance requirements of the road, corruption which leads to poor workmanship by the contractors, negligence of government officials who are authorized to supervise construction and lack of adequate resources to carry out maintenance of paved federal road in Ethiopia.

5.2 RECOMMENDATION

Based on the outcomes of this research, the following points are recommended to all stakeholders in order to diagnose the causes of frequent failures of the maintained paved Federal road in Ethiopia.

The maintained road condition has to be improved often because the users, the client, the way of living and socio-economic activity and environmental issues of the nation are changing dynamically;

- ERA must continuously assess the performance of the maintained road network to take timely corrective measures regarding the road condition;
- The Government of Ethiopia has to create opportunities to enhance the competitiveness and efficacy of local contractors in road maintenance;
- All parties have to take responsibility of risks that happen pre- and-post of maintenance work which can reduce the factors which affect the frequent failure of maintained roads;
- Setting the performance measures of the completed works; improving current level of efficiency regarding road maintenance by ERA staff and improving the maintenance culture is needed for maintained paved Federal road;
- ERA has to retreat to its PMS of current quality implementation level. In this respect, ERA has to build capacity of its staffs;
- ERA should give attention to advance that the current implementation practice has to promote asset management principles, especially in takeover of the completed project of maintained paved road;
- Consultants are directed to letting skilled technical staff to accomplish projects in a good way, so they would be able to overcome any technical or managerial problems that happen pertaining to maintained paved Federal road; and
- ERA should give adequate attention to road maintenance works and seek for various funding options to do with maintenance accumulation. In addition, it should exert emphasis on conducting preventive maintenance for pavements before they deteriorate into poor conditions; this can save a considerable amount of pavement maintenance budget.
- ERA should evaluate and adopt alternative maintenance strategies and maintenance treatment selection techniques to withstand scarcity of resources required to develop effective maintenance methods of Federal roads.
- Concerned body should check and maintain the absence and the existence condition of safety features in maintained road which adversely affect the maintained road surface and the road users.

5.3 PROPOSED FUTURE RESEARCH AREAS

The following research areas are proposed to complement/enhance this study**:**

- Investigating the root cause of road pavement failure in case of maintenance road.
- Alternative funding options for maintenance and reconstruction of Federal roads.
- Maintenance road pavement failures: cause and remedy
- Pavement treatment selection and maintenance alternatives in case of Federal road

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APPENDICES

APPENDIX-A

Addis Ababa Science and Technology University

College of Architecture and Civil Engineering

Department of Civil Engineering

Postgraduate Program in Construction Technology and Management

INFORMATION FOR RESPONDENTS

Dear participants;

The questionnaire is prepared by Construction Technology and Management post graduate student for conducting research on "**Investigating Causes for Frequent Failures of Maintained Paved Federal Roads in Ethiopia**" under the supervision of Dr **Alemayehu Ambo, (PhD)**.

The aim of this questionnaire is to study the Causes for Frequent Failures of Maintained Paved Federal Roads in Ethiopia. This questionnaire is required to be filled with exact relevant facts as much as possible. The information will be used for academic purposes only. Your answers will be kept completely confidential. It will be collected and presented as summaries only. The compiled results of this research may be published in scientific research journals or presented at professional conferences.

Therefore, your honest response is very much important input to my thesis. After all questionnaires are collected and analyzed. And also, interested participants of this study will be given feedback on the overall research results.

If you have any questions/queries please do not hesitate to contact me on:

- +251-937-668-931 or
- +251-932-151-643
- temgermamo@gmail.com

Thanks a lot for your time and assistance.

APPENDIX-B

A.

Questionnaire for client/ERA

The question below are related to your organization and yourself. Please indicate your response by ticking ('X' or '√') the appropriate box(es), and filling the blank spaces provided as appropriate.

PART-I

GENERAL BACKGROUND

1.1. Name of Organization:

1.2. Sex:

Male		Female	

1.3. Level of Academic

1.4. What is your academic background or field of training?

Second Degree	First Degree	Diploma	Other

1.5. Occupation

1.6. What is your current position?

Ethiopia Road Authority			
Top level management	**Mid-level management**	**Bottom level management**	**Other**

1.7. How many years have you been in the road sector?

0 – 5 years	5 – 10 years	10 – 15 years	15 – 20 years	20 – 25 years	Above 25 years

MAIN PART OF QUESTIONNAIRE

PART – II
GENERAL CAUSES

2.1. Which of the following factors are mostly affect the maintained paved Federal Roads? Please rate accordingly:

1. **Not cause**
2. **Least cause**
3. **Neutral**
4. **Cause**
5. **Major cause**

Causes		Scale indicator				
1	Quality of work	1	2	3	4	5
2	Required cost	1	2	3	4	5
3	Required period	1	2	3	4	5
4	Quality of design	1	2	3	4	5
5	Working load	1	2	3	4	5
6	Workers' skill	1	2	3	4	5
7	Data inventory	1	2	3	4	5
8	Data base	1	2	3	4	5
9	Heavy Traffic	1	2	3	4	5
10	Maintenance Culture	1	2	3	4	5
11	Highway Amenities	1	2	3	4	5
12	Laboratory and Insitu Tests on Soil	1	2	3	4	5
13	Quality Materials	1	2	3	4	5
14	Supervision	1	2	3	4	5
15	Knowledge Base	1	2	3	4	5
16	Weather Condition	1	2	3	4	5
17	Drainage supply	1	2	3	4	5
18	Soil Condition	1	2	3	4	5
19	Others	1	2	3	4	5

2.2. Rank the following factors (**as 1 up to 15**) that major cause to maintained Federal paved road failure.

No.	Causes	Rank	Remark
1	Inadequate government support		
2	Inadequate management capacity		
3	Knowledge and planning		
4	Dependency on donor funding		
5	Lack of efficient/competent contractor		
6	Slow administrative process by ERA		
7	Poor supervision by client (ERA)		
8	Lack of expert technical personnel by client (ERA)		
9	Extreme site condition like rain, flood etc.		
10	Extra work requirements of contractors		
11	Contract disputes or issues between the parties		
12	Delay on payment of contractor		
13	Shortage of material, manpower		
14	Uneven increase/fluctuation of material price		
15	Modification of plan or design related issues		
16	Political influence		
Specify			

2.3. For next questions please indicate your opinion where necessary by **circling the number** on rating scale.

No.	Quality related factors	Strongly disagreed	Disagreed	Neutral	Agreed	Strongly agreed
1	The level of quality achieved on the maintained paved road are sufficient.	1	2	3	4	5
2	Material quality control on the maintenance projects are sufficient.	1	2	3	4	5
3	The amount of resource allocated for implementing quality objectives are enough.	1	2	3	4	5

4	The current maintenance road contracting type will improve the service quality during the extended period.	1	2	3	4	5
5	The level of training (pre-and-on the job) for staffs are enough.	1	2	3	4	5
Risk sharing related factors						
1	Contractors do not need to take any responsibility for poor quality of works	1	2	3	4	5
2	Road maintenance construction project risks should be properly identified and shared between the contractor and the client	1	2	3	4	5
3	Risk sharing would bring a sense of discipline and responsibility to the contractor on road contracts	1	2	3	4	5
Improvement of efficiency						
1	Setting the performance measures of the completed works would help the contractors to do quality works	1	2	3	4	5
2	The current level of efficiency regarding road maintenance by ERA staff needs improvement	1	2	3	4	5
3	The current status of maintained paved Federal road need improvement regarding road maintenance project by ERA	1	2	3	4	5
Transparency						
1	The current contracting method can lower the level of possible corruption/mismanagement in the contracting process.	1	2	3	4	5
2	The nature of current contracting method mainly focuses on user satisfaction	1	2	3	4	5
Cost savings						
1	Under current contracting method, private sector workers (contractor's staff) would be more motivated than the traditional contracts	1	2	3	4	5
2	Current contracting method will reduce maintenance costs during the contract duration	1	2	3	4	5
Technical feasibility and Barriers						
1	Contractors capacity and commitment would be a problematic issue of concern in road maintenance.	1	2	3	4	5
2	Construction industry in Ethiopia is still underdeveloped to implement effective road maintenance contracts	1	2	3	4	5
3	Lack of government's budgetary allocation for the long-term commitment could be a problem	1	2	3	4	5
4	Contractors do not need to take any responsibility for poor quality of	1	2	3	4	5

	works					
5	The current level of efficiency regarding road maintenance by ERA staff needs improvement	1	2	3	4	5
General condition						
1	Maintained Federal Road condition status is good.	1	2	3	4	5
2	Present pavement evaluation method used by ERA is adequate for evaluating the pavement for structural, functional and safety of maintained road condition?	1	2	3	4	5
3	ERA apply different types of maintenance treatment selection techniques that are mandatory for recommending specific and cost effective remedial.	1	2	3	4	5
4	There is well-established Road maintenance management system in ERA for effective planning and management of pavement network.	1	2	3	4	5

2.4. Rate the following questions according to the following.

1. **Not cause**
2. **Least cause**
3. **Neutral**
4. **Cause**
5. **Major cause**

What are the main problems for practicing different road maintenance pavement evaluation methods in ERA that are mandatory for recommending the best maintenance option?						
1	Limited skilled man power	1	2	3	4	5
2	Lack of appropriate pavement management system	1	2	3	4	5
3	Budget constraint	1	2	3	4	5
4	Absence of appropriate machinery	1	2	3	4	5
5	Others	1	2	3	4	5
Specify						
What are the main constraints for implementation of effective road maintenance works in ERA?						
1	Limited skilled man power	1	2	3	4	5
2	Lack of appropriate pavement management system	1	2	3	4	5
3	Budget constraint	1	2	3	4	5
4	Absence of appropriate machinery	1	2	3	4	5
5	Lack of monitory and quality control	1	2	3	4	5
6	Others	1	2	3	4	5

Specify						
What are the main constraints to implement of Paved road maintenance management?						
1	Limited skilled man power	1	2	3	4	5
2	Lack of awareness for its benefits and costs of PMMS	1	2	3	4	5
3	Budget constraint	1	2	3	4	5
4	Absence of appropriate machinery	1	2	3	4	5
5	Political influence or involvement	1	2	3	4	5
6	Others	1	2	3	4	5
Specify						

2.5. Were the road maintenance projects completed by achieving the target?

1. Completed by achieving the target
2. Almost within the target
3. Totally failed to meet the target
4. Other reasons (please indicate)

2.6. Thinking about safety design on maintained roads, such as bends, parapets/ guardrails & other safety features, how would you rate them on the road?

1. Very good
2. Good
3. Neither good nor poor
4. Poor
5. Very poor

If the response to above is '4' or '5', what should be done to improve this?

_____

_____

_____

2.7. What are some of the considerations that are made when coming up with road maintenance design and appropriate drainage facility in Ethiopia? (More than one choice may be ticked).

1. State of road
2. Cost of construction
3. Class of the road
4. Period of construction
5. Topography

2.8. How often do you carry out inspection to ascertain the state of the maintained paved road in?

1. Monthly
2. Every three months
3. Every six months
4. Once a year
5. Any other (specify) _____.

2.9. What do you think is the remedy to the deteriorate state of the drainage system in maintained paved federal road?

1. Maintenance
2. Redesigning
3. Reconstruction
4. Any other (specify)

2.10. Could you explain the main difficulties or problems that ERA facing during the implementation of road maintenance project?

2.11. What is your opinion in the level of pavement maintenance works in Ethiopia compared with sustainable development?

2.12. Are there any factors which may affect the maintained Federal road in Ethiopia?

2.13. How do you measure the impact of maintenance roadworks on road users' satisfaction?

B.

Questionnaire for Contractors' and Consultants'

The questions below are related to your organization and yourself. Please indicate your response by ticking ('X' or '√') the appropriate box(es), and filling the blank spaces provided as appropriate.

PART-I

GENERAL BACKGROUND

1.8. Name of Organization:

1.9. Sex:

Male		Female	

1.10. Level of Academic

Second Degree	First Degree	Diploma	Other

1.11. What is your academic background or field of training?

1.12. What is your current position?

Position	**Contractor**	**Consultant**

1.13. How many years have you been in the road maintenance contract work?

0 – 5 years	5 – 10 years	10 – 15 years	15 – 20 years	21 – 25 years	Above 25 years

Main Part of Questionnaire

General causes

Part – III

2.14. Which of the following factors are mostly affect the maintained roads? Please rate accordingly:

6. **Not cause**
7. **Least cause**
8. **Neutral**
9. **Cause**
10. **Major cause**

Causes		**Rate**				
1	Quality of work	1	2	3	4	5

2	Required cost	1	2	3	4	5
3	Required period	1	2	3	4	5
4	Quality of design	1	2	3	4	5
5	Working load	1	2	3	4	5
6	Workers' skill	1	2	3	4	5
7	Data inventory and Data base	1	2	3	4	5
8	Heavy Traffic	1	2	3	4	5
9	Maintenance Culture	1	2	3	4	5
10	Highway Amenities	1	2	3	4	5
11	Laboratory and Insitu Tests on Soil	1	2	3	4	5
12	Quality Materials	1	2	3	4	5
13	Supervision	1	2	3	4	5
14	Knowledge Base	1	2	3	4	5
15	Weather Condition	1	2	3	4	5
16	Drainage supply	1	2	3	4	5
17	Soil Condition	1	2	3	4	5
18	Others	1	2	3	4	5
Specify						

2.15. Rank the following factors **(as 1 up to 13)** that cause most to maintained Federal paved road failure.

No.	**Causes**	**Rank**	**Remark**
1	Inadequate government support		
2	Dependency on donor funding		
3	Knowledge and planning		
4	Need for experienced large sized contractor		
5	Slow administrative process by client (government/ERA)		
6	Lack of expert technical personnel by client (ERA)		
7	Extreme site condition like rain, flood etc.		
8	Extra work requirements of contractors		

9	Contract disputes or issues between the parties		
10	Shortage of material, manpower		
11	Uneven increase/fluctuation of material price		
12	Modification of plan or design related issues		
13	Political influence		

2.16. For next questions please indicate your opinion where necessary by circling the number on rating scale.

No.	Quality related factors	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	Material quality control on the maintenance road are	1	2	3	4	5
2	The existing quality control policies that addresses all quality control issues are	1	2	3	4	5
3	The amount of resource allocated for implementing quality objectives are	1	2	3	4	5
4	The supervisory staffs' efficiency in achieving road maintenance project goal are sufficient.	1	2	3	4	5
	Risk sharing related factors					
1	Client has to take all the responsibilities of the project	1	2	3	4	5
2	Road maintenance construction project risks should be properly identified and shared between the contractor and the client	1	2	3	4	5
	Improvement of efficiency					
1	The current level of efficiency regarding road maintenance by ERA staff needs improvement	1	2	3	4	5
2	The current status of maintained paved Federal road need improvement regarding road maintenance project by ERA	1	2	3	4	5
	Cost					
1	Current contracting method will reduce maintenance costs during the contract duration	1	2	3	4	5
2	The nature of current contracting method mainly focuses on user satisfaction	1	2	3	4	5
	Technical feasibility and Barriers					
1	ERA has good contracting management experience and can easily	1	2	3	4	5

	adopt the current contracting method concept					
2	ERA has good knowledge and data of road networks, maintenance needs and costs which can be used to implement	1	2	3	4	5
4	The current contracting process lacks or restricts contractor from introducing new technology	1	2	3	4	5
3	Lack of government's budgetary allocation for the long-term commitment could be a problem	1	2	3	4	5

2.17. Indicate your opinion on the sufficiency of funding for road maintenance project provided by the government.

1. Available funding's are more than the total funds requested for work
2. All funding requested for work are provided
3. Half of the funds requested for work are provided
4. Very little funding is provided
5. Hardly any funding is provided

2.18. From your road maintenance design experience, was the drainage design appropriate?

1. Yes **2.** No

If the design was appropriate, what do you think is the problem?

1. Poor maintenance
2. Poor workmanship
3. Climate change
4. Poor farming practice
5. Topography

2.19. Do you think that there was laxity in the supervision of the contractor during the maintenance of the road?

1. Yes
2. No

Why do you think that was the case?

_____

_____.

2.20. Do you think poor farming practices are to blame for the erosion of the road and the surrounding?

1. Yes
2. No

If your answer is yes, what do you recommend as the best farming practice in the area?

_____

_____.

2.21. What is your opinion in maintained paved road serviceability in Ethiopia?

2.22. What is your opinion in maintenance activities for road shoulders, water drainage systems, lights and traffic signs in Ethiopia?

2.23. What is your opinion in the level of pavement maintenance works in Ethiopia compared with sustainable development?

2.24. Are there any factors which may affect the maintained road in Ethiopia Federal Road?

2.25. Finally, can you give any suggestion for further improvements in road-maintenance?

C

Questionnaire for Maintained Road Users'

Please indicate your response by ticking ('X' or '√') the appropriate box(es), and filling the blank spaces provided as appropriate.

PART-I

GENERAL BACKGROUND

1.14. Sex:

Male		Female	

1.15. Level of Academic

Second Degree	First Degree	Diploma	Other

1.16. Work

Main Part of Questionnaire

PART-II

2.26. How many times do you travel on the road in a month?

1. Less than once
2. 1-3 times
3. 4-7 times
4. 8-10 times
5. More than 10 times

2.27. In your opinion has the condition of the road improved in the last five years? It has…

1. Improved substantially
2. Improved marginally
3. Remained same
4. Declined somewhat
5. Substantially declined

2.28. During the last five years traveling time between particular places you travel frequently on the road has reduced or increased?

1. Substantially reduced
2. Reduced marginally
3. Remained same
4. Increased somewhat
5. Increased substantially

2.29. Due to the condition of the maintained road has the fuel consumption of your vehicle declined or increased?

1. Substantially decreased
2. Decreased somewhat
3. Remained same
4. Increased somewhat
5. Substantially increased

2.30. Due to the condition of the road has overall maintenance cost of your vehicle increased or decreased?

1. Substantially decreased
2. Decreased somewhat
3. Remained same
4. Increased somewhat
5. Substantially increased

2.31. Which of the following factors are mostly affect the maintained roads? Please rate accordingly:

11. Not cause **13. Average** **15. Major cause**
12. Least cause **14. Cause**

Causes		**Rate**				
1	Quality of work	1	2	3	4	5
2	Required cost	1	2	3	4	5
3	Required period	1	2	3	4	5
4	Workers' skill	1	2	3	4	5
5	Heavy Traffic	1	2	3	4	5
6	Maintenance Culture	1	2	3	4	5
7	Quality Materials	1	2	3	4	5
8	Knowledge Base	1	2	3	4	5
9	Weather Condition	1	2	3	4	5
10	Drainage supply	1	2	3	4	5
11	Soil Condition	1	2	3	4	5
12	Others	1	2	3	4	5
Specify						

2.32. Keeping in view, the maintained paved road safety and convenience on your roads, how do you rate the following?

1. **Very poor**
2. **Poor**
3. **Neither good nor poor**
4. **Good**
5. **Very good**

S.No.	**Factor**	**`Rating**				
		1	2	3	4	5
1	Quality of road markings on these roads (such as painted lines, reflection signs, pedestrian crossing markings, etc)	1	2	3	4	5
2	Adequacy of warning / road signs	1	2	3	4	5
3	Visibility of warning/ roads signs during day and night	1	2	3	4	5
4	Positioning/ location of warning / road signs	1	2	3	4	5

5	Adequacy of milestones / distance signs	1	2	3	4	5
6	Visibility of milestones / distance signs	1	2	3	4	5
7	Availability of streetlights on these roads	1	2	3	4	5
8	Conducive surface texture of road.	1	2	3	4	5

2.33. How congested is the maintained road? (Congestion means reduced traffic- speed due to overcrowding of vehicles).

1. Absolutely free from congestion
2. Somewhat free
3. Neither free nor congested
4. Somewhat congested
5. Highly congested

2.34. What do you think about quality of maintained road-surface, smoothness and surface appearance on the road?

1. Very good
2. Good
3. Neither good nor poor
4. Poor
5. Very poor

2.35. How satisfied are you with the overall condition of maintained road?

1. Highly satisfied
2. Somewhat satisfied
3. Neither satisfied nor dissatisfied
4. Somewhat dissatisfied
5. Highly dissatisfied
6. Not applicable

2.36. How safe do you feel while commuting on these roads?

1. Very unsafe
2. Somewhat unsafe
3. Neither safe nor unsafe
4. Somewhat safe
5. Very safe

2.37. If response to above is '1' or '2', ask) why do you feel unsafe on these roads?

No.	**Factors**	**Tick**	No.		**Tick**
1	High volume of traffic		7	Bad weather	
2	Heavy vehicles		8	Slippery roads in rainy seasons	
3	Poor/ aggressive driving		9	Absence of streetlights	
4	Absent/ loose parapets		10	Sharp turns	
5	Unsafe retaining walls		11	Bad signage	
6	Absence of plantation at places prone to land sliding	Specify			

2.38. Thinking about safety design on roads, such as bends, parapets/ guardrails & other safety features, how would you rate them on the road?

1. Very good
2. Good
3. Neither good nor poor
4. Poor

5. Very poor

If the response to above is ‘4’ or ‘5’, what should be done to improve this?

2.39. Do you think poor farming practices are to blame for the erosion of the road and the surrounding?

1. Yes
2. No

If your answer is yes, what do you recommend as the best farming practice in the area?

2.40. In your opinion how do you find the condition of the maintained road drainage system?

1. Very good condition
2. Good condition
3. Fair condition
4. Poor condition

2.41. How does poor drainage affect you as a road user?

1. Runoff on the road block the road
2. Runoff wash away the bridges
3. Runoff cuts through the road
4. Water leaves debris on the road surface
5. Any other (specify)

2.42. In your own view, how satisfied are you as a road user or resident with the state of maintained paved road?

1. Extremely satisfied
2. Satisfied
3. Dissatisfied
4. Extremely dissatisfied

2.43. Are there any factors which may affect the maintained road in Ethiopia Federal Road?

2.44. What makes the road maintenance accurate?

2.45. Can you give any suggestion for further improvements in road-maintenance?